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GEOLOGY.

A GLANCE AT THE SCIENCES.

BOSTON:
BRADBURY, SODEN & COMPANY.

A

GLANCE

AT THE

PHYSICAL SCIENCES;

OR THE

WONDERS OF NATURE,

IN

EARTH, AIR, AND SKY:

BY THE AUTHOR OF

PETER PARLEY'S TALES.

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A GLANCE AT THE SCIENCES.

INTRODUCTION.

NATURAL OR PHYSICAL SCIENCE is as boundless in its scope as the extent of the universe. It does not confine its researches to the narrow circle within our own observation: it is not content with the investigation of objects presented to the naked eye: it goes with the telescope into the heavens, and descends with the microscope into the atom — every where discovering materials for its consideration. Nor is it absorbed with observations upon the forms and hues of material objects: it seeks out the hidden laws of the universe, the principles by which the Architect of the earth and heavens constructs and governs his boundless dominions.

We are apt to wrap up the true idea of scientific investigations in a bald and chilling phraseology: we call them *studies of nature;* but they are, in truth, studies into the ways of God. What is *nature*, separate from that active and intelligent Being to whom

we are indebted for life and light,—that Being who gave us the Bible as well as the Sun, and is as truly the moral as he is the natural Governor of the universe?

The true mode of pursuing scientific studies is to regard them as investigations into the works of the Almighty, and every where, as well in the contemplation of the starry firmament as in scrutinizing the more familiar objects of our own globe, to realize the presence of the Creator. In this way, science unseals the volume of Nature's revelation, to the most noble and exalting purposes.

"While the telescope," says Dr. Chalmers, "enables us to see a system in every star, the microscope unfolds to us a world in every atom. The one instructs us that this mighty globe, with the whole burden of its people and its countries, is but a grain of sand in the vast field of immensity: the other, that every atom may harbor the tribes and families of a busy population. The one shows us the insignificance of the world we inhabit: the other redeems it from all its insignificance; for it tells us that, in the leaves of every forest, in the flowers of every garden, in the waters of every rivulet, there are worlds teeming with life, and numberless as are the stars of the firmament. The one suggests to us that, above and beyond all that is visible to man, there may be regions of creation which sweep immeasurably along, and carry the impress of the Almighty's hand to the remotest scenes of the universe;

the other that, within and beneath all that minuteness which the aided eye of man has been able to explore, there may be a world of invisible beings; and that, could we draw aside the mysterious curtain which shrouds it from our senses, we might behold a theatre of as many wonders as astronomy can unfold; a universe within the compass of a point, so small as to elude all the powers of the microscope, but where the Almighty Ruler of all things finds room for the exercise of His attributes, where He can raise another mechanism of worlds, and fill and animate them with all the evidence of His glory."

How interesting, how instructive, is science, while we thus walk its paths in the light of God's image, and with the constant assurance that, while He thus pursues His vast operations, He is still presiding over the beating of our hearts, and that not even the sparrow falls unnoticed to the ground! How comparatively barren and desolate are the works of creation, if the Christian's God is every where invisible, and the whole phenomena of nature are to be resolved into an inscrutable series of causes and consequences!

In the course of the following pages, we propose only to present a rapid and distinct outline of *Physical Science*, as it is now exhibited in the works of learned men. Within the present century, the march of knowledge has been rapid beyond example, and at the same time, the most wonderful discoveries have been

brought within the reach of every reader. Philosophy is no longer sealed up in learned languages, and kept under the lock and key of colleges and universities. In the compass of this little volume, we hope to place within the reach of our readers, not only the most important results of the researches of Herschel and Laplace into the mechanism of the heavens, but of those of Lyell, Mantel, and others, into the structure of our earth; to present the wonders of the telescope and the microscope; in short, to open the book of natural philosophy, and take a glance at its wonderful revelations, in respect to the stars above, and the animal, vegetable, and mineral kingdoms here below.

ASTRONOMY.

"ASTRONOMY is that department of knowledge which has for its object to investigate the motions, the magnitudes, and distances, of the heavenly bodies; the laws by which their movements are directed, and the ends they are intended to subserve in the fabric of the universe. This is a science which has in all ages engaged the attention of the poet, the philosopher, and the divine, and been the subject of their study and admiration. Kings have descended from their thrones to render it homage, and have sometimes enriched it with their labors; and humble shepherds, while watching

their flocks by night, have beheld with rapture the blue vault of heaven, with its thousand shining orbs, moving in silent grandeur, till the morning star announced the approach of day. The study of this science must have been coeval with the existence of man; for there is no rational being who has for the first time lifted his eyes to the nocturnal sky, and beheld the moon walking in brightness amid the planetary orbs and the host of stars, but must have been struck with admiration and wonder at the splendid scene, and excited to inquiries into the nature and destination of those far-distant orbs. Compared with the splendor, the amplitude, the august motions, and the ideas of infinity which the celestial vault presents, the most resplendent terrestrial scenes sink into inanity, and appear unworthy of being set in competition with the glories of the sky.

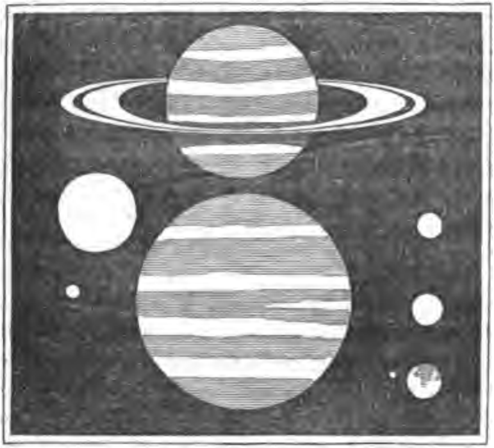
"When, on a clear autumnal evening, after sunset, we take a serious and attentive view of the celestial canopy; when we behold the moon displaying her brilliant crescent in the western sky; the evening star gilding the shades of night; the planets moving in their several orbits; the stars, one after another, emerging from the blue ethereal, and gradually lighting up the firmament till it appears all over spangled with a brilliant assemblage of shining orbs; and particularly when we behold one cluster of stars gradually descending below the *western* horizon, and other clusters emerging from the *east*, and ascending, in unison, the canopy of heaven; when we contemplate the whole celestial vault, with all the shining orbs it contains, moving in silent grandeur, like one vast concave sphere, around this lower world and the place on which we stand — such a

scene naturally leads a reflecting mind to such inquiries as these: Whence come those stars which are ascending from the east? Whither have those gone which have disappeared in the west? What becomes of the stars, during the day, which are seen in the night? Is the motion which appears in the celestial vault *real*, or does a motion in the Earth itself cause this appearance? What are those immense numbers of shining orbs which appear in every part of the sky? Are they mere studs, or tapers, fixed in the arch of heaven, or are they bodies of immense size and splendor? Do they shine with borrowed light, or with their own native lustre? Are they placed only a few miles above the region of the clouds, or at immense distances, beyond the range of human comprehension? Can their distance be ascertained? Can their bulk be computed? By what laws are their motions regulated—and what purposes are they destined to subserve in the great plan of the universe?"

These, and similar questions, it is the province of *Astronomy* to resolve, so far as human intelligence can compass them. Vast as is the subject, and far as it may seem beyond our reach, yet in no other science have there been such gradual and constant accessions of knowledge as in this. It may at the same time be observed, that in none so much remains to be discovered. Laplace, who knew more than any other man of the mechanism of the heavens, said earnestly, on his deathbed, "What we know is little—what we do not know is immense." The same feeling was entertained by Newton, at the moment of his immortal discovery of the principle of gravitation, when,

with the modesty of all great minds, beside whose infinite aspirations the highest possible attainment is ever insignificant, he exclaimed, "I am but as a child standing upon the shore of the vast, undiscovered ocean, and playing with a little pebble, which the waters have washed to my feet."

THE SOLAR SYSTEM.



Comparative Size of the larger Planets.

The Solar System is composed of a great central luminary, the Sun, whose mass is supposed to be made up of opaque matter, like the Earth,— the atmosphere alone being luminous,— and a number of comparatively small engirdling bodies, the planets, comets, &c., which revolve around it in various periods. The comparative

size of these bodies, and their respective distances from each other, may be estimated by the following illustration. On a level field, place a globe, two feet in diameter; this will represent the SUN. MERCURY will be represented by a grain of mustard seed, on the circumference of a circle 164 feet in diameter; VENUS, by a pea, on a circle 284 feet in diameter; the EARTH, a somewhat larger pea, on a circle of 430 feet; MARS, a large pin's head, on a circle of 654 feet; JUNO, CERES, VESTA, and PALLAS, grains of sand, in orbits of from 1000 to 1200 feet; JUPITER, an orange, in an orbit of nearly half a mile across; SATURN, a small orange, in an orbit of four fifths of a mile; and URANUS, a cherry, on the circumference of a circle more than a mile and a half in diameter. We shall now proceed to give a more particular account of these members of the solar system.

THE SUN.

The Sun, when viewed with a telescope, presents the appearance of an enormous globe of fire, frequently in a state of violent agitation or ebullition. Black spots, of irregular form, rarely visible to the naked eye, sometimes pass over his disk, in a space of about fourteen days; one was measured by Sir W. Herschel, in 1779, and found to be 30,000 miles in breadth. A spot, when first seen on the eastern edge, appears like a line, progressively extending in breadth, till it reaches the middle, when it begins to contract, and ultimately disappears at the western edge. In some rare instances, spots reappear on the eastern side, and are even permanent for two or three revolutions; but they generally change their aspect in a few days, and disappear.

Astronomers inform us, that sometimes 50 spots are seen, at once, on the Sun's surface. From 1611 to 1629, it was hardly free from spots; while from 1650 to 1670, scarcely any were to be seen. The same irregularity has been frequently noticed. In October, 1827, 150 spots were noticed at one time.

Sometimes, several small spots unite into a large one; again, a large one separates into smaller ones, which soon vanish. These phenomena induced Herschel to suppose the Sun to be a solid, dark nucleus, surrounded by a vast atmosphere, almost always filled with luminous clouds, occasionally opening and disclosing the opaque mass within.

The speculations of Laplace were different; he imagined the solar orb to be a mass of fire, and that the violent effervescences and explosions, seen on its surface, are occasioned by the eruption of elastic fluids formed in its interior; and that the spots are enormous caverns, like the craters of our volcanoes. The theory of Herschel, however, is that most generally received by learned men.

"The *magnitude* of this vast luminary is an object which overpowers the imagination. Its diameter is 880,000 miles; its circumference, 2,764,600 miles; its surface contains 2,432,800,000,000 of square miles, which is twelve thousand three hundred and fifty times the area of the terraqueous globe, and nearly fifty thousand times the extent of all the habitable parts of the Earth. Were its centre placed over the Earth, it would fill the whole orbit of the moon, and reach 200,000 miles beyond it on every hand. Were a person to travel along the surface of the Sun, so as to pass along

every square mile on its surface, at the rate of thirty miles every day, it would require more than two hundred and twenty millions of years before the survey of this vast globe could be completed.

"It would contain within its circumference more than thirteen hundred thousand globes as large as the Earth, and a thousand globes of the size of Jupiter, which is the largest planet of the system. It is more than five hundred times larger than all the planets, satellites, and comets belonging to our system, vast and extensive as some of them are. Although its density is little more than that of water, it would weigh 3360 planets such as Saturn, 1067 planets such as Jupiter, 329,000 globes such as the Earth, and more than 2,000,000 of globes such as Mercury, although its density is nearly equal to that of lead."

The most obvious *apparent* motion of the Sun is, that it seems to rise in the morning in the east; to traverse the heavens in a westerly direction, and at last to disappear beneath the horizon. But it is now well understood that the Sun is quiescent, and that the seeming motion we have described is occasioned by the daily rotation of the Earth on its axis. But although the Sun stands in the centre of the system of planets, it appears that it revolves on its axis like the other heavenly bodies, and that it completes its revolution in twenty-five days and ten hours. Every part of its equator moves at the rate of 4352 miles an hour. It is also considered probable that the Sun, attended by its troop of planets, makes a vast journey in space, but whether in a straight line, or in an immense circle, is still matter of conjecture.

THE PLANET MERCURY.

This planet is 37,000,000 miles from the Sun, and is the nearest that has yet been discovered. It is seldom seen by the naked eye; its daily revolution is performed in 24 hours, 5 minutes, and 20 seconds. It revolves round the Sun in the space of 87 days and 23 hours. When viewed with the telescope, it presents the various phases of the moon, from a crescent to the full, round orb.

Few discoveries have been made on this planet, owing to the dazzling splendor of its rays. Mountains, however, have been seen; and one of them is said to be upwards of ten miles in height, which is nearly twice the elevation of the loftiest peaks on our globe. The light upon its surface is supposed to be seven times greater than upon the Earth. If the planet be inhabited, it is obvious that the organization of the eye must be different from that of ours. It is supposed that the intensity of heat is not greater than with us.

The diameter of Mercury is 3200 miles. Its surface contains 32,000,000 of square miles. It is about one fifteenth the size of the Earth.

In its revolution round the Sun, its motion is swifter than that of any other planet, being 109,800 miles every hour, 1830 miles every minute, and more than 30 miles during each beat of the pulse. The density of matter composing Mercury is twice that of the Earth, yet it would require two millions of globes, of the same size, to make one of the size and density of the Sun.

THE PLANET VENUS.

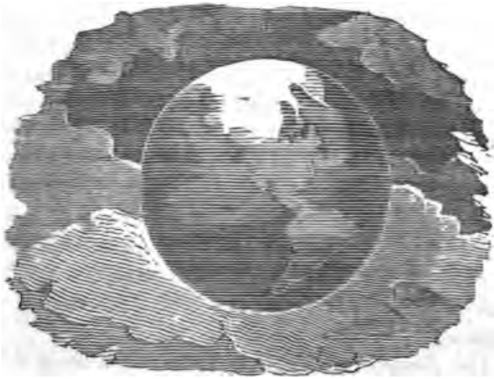
With the exception of the Sun and moon, this is the most splendid of the heavenly bodies. It appears like a shining lamp amid the lesser orbs of night; and, at particular seasons, ushers in the morning dawn and the evening twilight. But if such is its appearance to the naked eye, it becomes a still more interesting object, when viewed with the telescope of the astronomer. It passes through all the phases of the moon, from the crescent to the gibbous form; and formerly several dark spots were noticed upon its surface. Its daily rotation is performed in 23 hours and 20 minutes. Several mountains have been discovered, and one of them is nearly twenty miles high, or five times the height of Chimborazo. It possesses an atmosphere supposed to be about three miles in height, and is supposed to have a satellite, or moon; but this is not determined with certainty.

The diameter of Venus is 7800 miles, being a little less than that of the Earth. It does not appear that any great quantity of water exists upon it. Its quantity of light is about twice that of the Earth. It revolves in an orbit of 433,800,000 miles, in the space of 224 days and 16 hours. Its distance from the Sun is 68,000,000 miles, and from the Earth, when nearest to us, about 27,000,000 miles. Its matter is in a slight degree less dense than that of the Earth.

THE EARTH.

Although the Earth appears to be larger than all the heavenly orbs, it is, in fact, infinitely smaller, and holds

a rank with the inferior bodies of the universe. Although it appears to the eye of sense immovably fixed, it has a double motion — one on its own axis, and one around the Sun, by which it is transported, with all its continents, and oceans, and kingdoms, at the rate of more than a thousand miles a minute.



This planet, like all the other heavenly bodies, has a globular shape ; but it is not a perfect globe, it being depressed at the poles. The diameter, through the poles, is 34 miles less than through the equator. This curious fact was discovered by perceiving that the pendulum of a clock had 140 vibrations less in a day, at Paris, than at Cayenne, in Guiana. Further observations were made, and it was found that this variation was uniform, and that the vibrations regularly diminished in proceeding northward from the equator. This led to many curious investigations, which resulted in demonstrating

the fact we have above mentioned. It is interesting to observe, that so simple a circumstance as the slower movement of clocks, in a southern latitude, should have led to so wonderful a discovery in science as the depression of the poles of the Earth.

The prominent feature of the Earth's surface is its division into land and water; the latter predominates, occupying 148,000,000 square miles, or more than two thirds of the face of the globe. It contains 296,000,000 of cubical miles of water, sufficient to cover the whole globe to the depth of more than half a mile. This superabundance of water is probably peculiar to our planet, and is conjectured to have resulted from the deluge.

The surface of the Earth is further diversified by ranges of mountains, stretching across the continents and islands, and giving variety to the landscapes of every country. From these mountains flow myriads of streams, fertilizing the valleys through which they take their course, and at last losing themselves in the ocean. An atmosphere, about 100 miles in height, surrounds this terraqueous mass, which, put in motion, forms the winds, which fan the earth with gentle breezes, or heave the ocean into billows. It is the theatre where the lightnings flash, and the thunders roll; where the meteor sweeps with its fiery train, and the Aurora Borealis displays its fantastic coruscations.

Were the Earth viewed from some point in the heavens — as the moon, for instance — it would have somewhat the same appearance as the moon does to us. The distinction between its seas, oceans, continents,

and islands, would be clearly marked, and would appear like brighter or darker spots upon its disk. The continents would appear bright, and the oceans of a darker hue, because water absorbs a great part of the solar rays that fall upon it.

The Earth, as it would appear from the Moon.

We are quite well acquainted with the surface of the Earth, but our knowledge of its internal structure is very limited. The deepest mine does not extend more than a mile from the surface; and this depth, compared with the diameter of the Earth, is not more than the scratch of a pin upon the surface of an artificial globe. What materials are to be found within the bowels of the Earth, will be forever beyond the power of mortals to determine. It is supposed, however, and not without reason, that, while the crust of the globe consists of

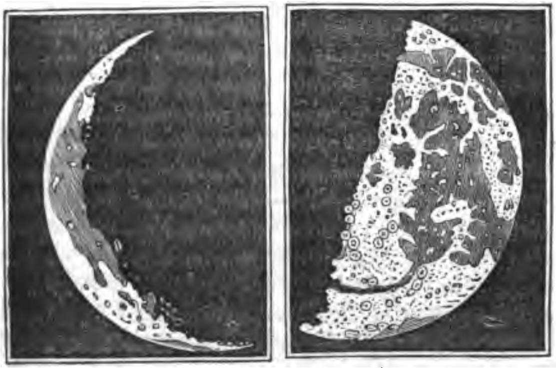
a framework of rocks, mingled with earth and water, the centre is occupied with a vast metallic mass in a state of fusion from heat.

The density of the whole Earth, bulk for bulk, is estimated at five times the weight of water, so that it would counterpoise five globes of water of the same size. The diurnal revolution of the Earth is performed in 23 hours, 56 minutes. This gives rise to day and night; to which arrangement of nature, the economy of the vegetable as well as of the animal world is adjusted. The annual revolution of the Earth is accomplished in 365 days, 5 hours, 45 minutes, and 51 seconds. From this proceed the varieties of the seasons: spring, summer, autumn, and winter, follow each other in constant succession, diversifying the scenery of nature, and marking the different periods of the year. In those countries which lie in the southern hemisphere of the globe, as at Buenos Ayres and the Cape of Good Hope, December, January, and February, are the summer months, while in this northern hemisphere, these are the winter months, when the weather is coldest and the days are shortest.

The average distance of the Earth from the Sun is 95,000,000 miles. The length of the path annually travelled by the Earth in its orbit is 567,019,740 miles, or about 1000 miles a minute, or 17 miles a second.

The *Moon*, a satellite of our own planet, is the heavenly body of which we have the most accurate knowledge. Its surface exhibits a very large number of mountains, almost uniformly of a circular or cusp-shaped form, the larger ones having, for the most part, flat bottoms within, from which rises, in the

centre, a small, steep, conical hill. They offer, in its highest perfection, the true volcanic character, as it may be seen in the crater of Vesuvius. In some of the principal ones, decided marks of volcanic stratification, arising from successive deposits of ejected matter, may be clearly traced with powerful telescopes.



Telescopic Views of the Moon.

It is, moreover, a singular fact in the geology of the moon, that, although nothing like water can be perceived, yet there are large regions perfectly level, and apparently of an alluvial character. The mountains are known by their shadows, which are distinctly visible, and which are long when they are near the boundary of light and darkness, or when the sun is in the horizon, and disappear when they are 90 degrees from that boundary, or when the sun is overhead.

The moon is generally believed either to have no atmosphere, or one of such tenuity as not to equal in

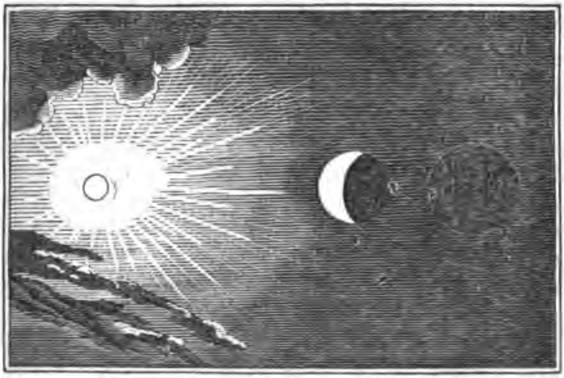
density the contents of an exhausted receiver. From this it has been inferred that there are no fluids at the surface of the moon — since, if there were, an atmosphere must be formed by evaporation. Without air and water, it would seem that the moon cannot be inhabited; or, if life exist there, it cannot be in any form which is exhibited in our own planet. The days and nights in the moon are each 14 days and three quarters in length: the intense heat and cold which must thus alternate would destroy human life, even on the supposition that vegetation could be maintained.*

The moon, like all other heavenly bodies, appears to rise in the east and set in the western part of the horizon. Its real motion, however, is in a contrary direction — that is, from west to east, or in the same direction in which all the planets move round the Sun. It is a dark body, deriving its light from the Sun, and occasionally a faint light, by reflection of the Sun's rays, from the Earth. It is about 240,000 miles from the centre of the Earth, and pursues its course around this planet at the rate of 2300 miles an hour. It

* Such are the conclusions of most philosophers. Yet Dr. Dick observes, that "probably the moon is surrounded with a fluid which serves the purpose of an atmosphere, though it may be different in its nature and composition from that which surrounds the earth." He hence concludes that the moon may be inhabited, and, indeed, proceeds to assume this as the fact. Upon this, he makes a great variety of ingenious suggestions, and even supposes it to be possible to trace the operations of intelligent beings upon its surface. Dr. Olbers is also of the opinion, that the moon is inhabited by rational creatures, and that its surface is covered with vegetation not very dissimilar to that of our Earth.

performs its revolution in 29 days, 12 hours, and 44 minutes. It is a curious fact, that the revolution on its axis is performed in the same time as its revolution round the Earth. Accordingly, it always presents the same face to the Earth, so that we never see more than one side of it.

The moon appears nearly as large as the Sun; but it is but about one fiftieth the size of the Earth, and it would take 63,000,000 of globes, of the size of the moon, to make one of the Sun.

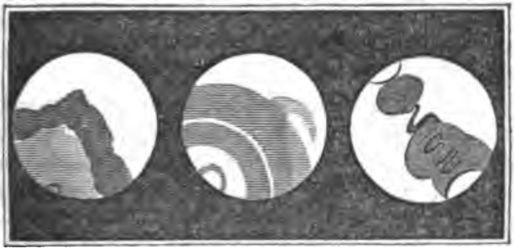


An Eclipse of the Sun.

When the Earth comes between the Sun and moon, it casts its shadow upon the latter, which is then said to be eclipsed. An eclipse of the Sun is occasioned by the moon coming between the Earth and the Sun, thus cutting off its rays. An eclipse of the moon always occurs at the time of its full; eclipses of the Sun occur at the time of the new moon. It is one of the

triumphs of science, that these sublime phenomena, formerly so fruitful a source of superstitious fear and ominous prediction, are now the subject of the most exact calculation, and are as much divested of every mysterious attribute, as the common events of sunrise and sunset.

THE PLANET MARS.



Telescopic Appearances of Mars.

The Earth is placed, in the solar system, between the orbits of Venus and Mars. The latter is 145,000,000 miles from the Sun. When nearest the Earth, its distance is 50,000,000; when farthest, 240,000,000 miles. This fact will explain, what most persons have noticed, that this planet is at one time almost imperceptible, and at another seems to vie with Jupiter in magnitude and splendor. The diurnal revolution of Mars is performed in 24 hours, 39 minutes, 29 seconds. Its orbit is 900,000,000 miles in circumference. It performs this circuit in 1 year and 322 days. Its rate of motion is 54,649 miles every hour, which is more than a hundred times greater than the utmost velocity of a cannon-ball.

When viewed through a telescope, this planet pre-

sents a variety of dark spots and belts, though of different forms and shades. Luminous spots, and zones, have also been discovered, which frequently change their appearance, and alternately disappear and return. The latter are supposed to be occasioned by snow; the former are conjectured to be occasioned by a distribution of the face of the planet into land and water. It is supposed that one third of the surface is occupied by the latter. It is probable that the diversities in the appearance of Mars, as seen through a telescope, are in part occasioned by clouds.

Mars has a variety of seasons, similar to ours, and it bears a closer resemblance to the Earth than any other planet. It is 4200 miles in diameter, a little more than half that of our globe. No moon or satellite has been discovered, as attendant upon it.

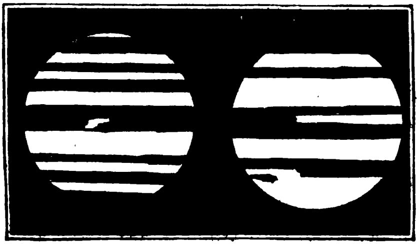
CERES, PALLAS, JUNO, AND VESTA.

The immense interval which lies between the orbits of Mars and Jupiter had led the astronomers to surmise that some planet, of considerable magnitude, might possibly exist within this limit. But instead of one, four small orbs have been recently discovered, which bear the above names. The first, called Ceres, was discovered by Piazzi, in Sicily, on the first day of the present century. Pallas was discovered in March, 1802, by Olbers; Juno by Harding, in September, 1804, and Vesta by Olbers, in March, 1807.

These four planets are invisible to the naked eye, and we are, therefore, indebted to the telescope for a knowledge of their existence. It is conjectured, and not without reason, that these four planets were once

united in one, and that by some mighty force they have been sundered, and thrown into their present orbits. Their diameter has not been ascertained with precision. Herschel reckons that the largest does not exceed 500 miles in circumference. In several respects, they are marked with peculiarities. The orbits of some of them cross each other, which is not the case with any other planet. They revolve in nearly the same mean distances from the Sun,—that is, about 260,000,000 miles. Their annual revolutions, also, are nearly the same; being little more than four years. They are smaller than the other planets—Ceres containing but one eighth part as many solid miles as Mercury. It is probable that they are even smaller than the moons of Jupiter, Saturn, or Uranus.

THE PLANET JUPITER.



Telescopic Views of Jupiter.

We now come to one of the most splendid orbs in the planetary system. Jupiter is 495,000,000 miles from the Sun, and the circumference of its orbit is 3,110,000,000 of miles. Around this orbit it moves in 11 years, 315 days, at the rate of about 30,000 miles

an hour. Its nearest approach to the Earth is about 600,000,000 miles. A cannon-ball, flying at the rate of 500 miles an hour, would reach it in a little less than a hundred years. The daily rotation of Jupiter is performed in 9 hours, 59 minutes, 49½ seconds. Its circumference is 278,600 miles. Its density is a little more than that of water, or five times less than that of the Earth. It is the largest planet in our system, being 1400 times larger than the Earth.

When viewed with a powerful telescope, this planet presents a splendid appearance. Its surface, then, seems larger than the full moon to the naked eye. Its disk is diversified with darkish parallel stripes. The four satellites, revolving around the planet, generally appear in a straight line with each other. Sometimes, only two of them are visible, the other two being eclipsed either by the disk or the shadow of Jupiter; at other times, all are seen at once. From their changing appearance, it it supposed that the dark belts of Jupiter are the body of the planet, seen through something analogous to clouds, floating in its atmosphere at a considerable elevation above its surface.

The day and night in Jupiter are nearly equal. The intensity of its solar light is 27 times less than that of the Earth. It is greatly depressed at the poles; the diameter of the equator being 6,300 miles greater than that at the poles.

THE PLANET SATURN.

This planet may be considered in many respects the most magnificent and interesting body within the limits of the planetary system. Taking into view its satellites

and rings, it has a greater quantity of surface than even the globe of Jupiter; and its majestic rings constitute the most singular and astonishing phenomena that have yet been discovered in the sidereal universe.

Its distance from the Sun is 906,000,000 of miles, which is nearly twice the distance of Jupiter, or ten times that of the Earth. The circumference of its orbit is 5,695,000,000 of miles. When nearest, it is 811,000,000 of miles from the Earth. A steam carriage, travelling at the rate of 20 miles an hour, would not reach it in less than 4629 years.

This planet revolves round the Sun in the space of about 29½ years. Its motion is at the rate of 22,000 miles an hour. Its diurnal rotation is performed in 10 hours, 29 minutes, and 17 seconds. This rotation is perpendicular to the plane of its rings. Its proportion of light from the Sun is but one 90th of our own. It is 79,000 miles in diameter, and nearly a thousand times larger than the Earth. When viewed with a telescope, it exhibits belts similar to those of Jupiter, and disposed in lines parallel to the ring. These are permanent, and probably indicate a diversity of surface, either of land or water, or some substance with which we are unacquainted. Its figure is spheroidal, with considerable polar depressions.

The density of Saturn is about the same as cork, or one half that of water. This is taking into view its whole bulk; if its centre is hollow, its exterior parts may be as hard as rock. It has been said, that "while a native of earth could hardly move upon Mercury, from the strong attractive power pulling him to the ground, he could, on the planet Saturn, leap sixty feet

high as easily as he could here leap a yard." These suppositions are, however, unsound. The density of Mercury is double that of the Earth, and nearly that of lead; but it must be considered that the attraction in the planets is somewhat in proportion to the masses of matter which they contain, and not in proportion to their density. Taking this principle into view, the attraction upon the surface of Saturn is a little greater than that of the Earth. It is supposed that there is no planet in the solar system, with the exception of Jupiter, on which an inhabitant of the Earth might not move about as easily as upon our globe; and on Jupiter, he would experience little more than double the weight he now feels.

One of the most astonishing phenomena that have yet been discovered in the heavens, is the double ring of Saturn. As generally observed, we have a side view, in which case it presents nearly the following appearance.

The outside diameter of the exterior ring is 179,000 miles; the outside diameter of the interior ring is 152,000 miles. The breadth of the dark space between the two rings is 1800 miles; so that a body nearly as large as our moon could pass through it. The breadth of the exterior ring is 7200 miles; of the interior, 20,000 miles. The thickness of the ring is

not supposed to be over 100 miles. When it is presented edgewise to the earth, it can only be seen with a powerful glass. This ring is not exactly circular, but slightly elliptical. It is ascertained to have a swift rotation around Saturn, which is completed in about 10 hours and a half. The outer edge of the ring is 550,000 miles in circumference, and moves at the rate of more than 1000 miles a minute.

This double ring is a compact, solid substance, for its shadow is distinctly seen on the planet which it encloses. It is not certain that both parts of the ring have exactly the same periods of rotation. It is about 30,000 miles from the surface of the planet, always keeps the same relative position, and attends it in all its movements. One side of it contains 146 times the surface of the whole of our globe!

These rings will appear, to the inhabitants in the firmament of Saturn, like large luminous circles or semicircles of light, stretching across the heavens from east to west, and occupying one fourth part of the sky. As they are brighter than the body of the planet, it is probable that they are of some substance which is fitted to reflect the solar light with peculiar splendor. How glorious, and diversified, must be the celestial scenery thus presented!

Saturn has seven satellites, all revolving beyond its ring. The nearest is 18,000 miles beyond its exterior edges; the most distant is 2,297,000 miles from the planet, and performs its circuit in about 79½ days. The largest is supposed to be about the size of Mars, or 4200 miles in diameter. These satellites must afford a splendid appearance from the planet, as some of them must seem nine times larger than our moon.

If we take this into view, in connection with the sublime splendor of the rings, it might almost seem that Saturn is fitted up to be the abode of some favored beings, upon whom the Creator has lavished the wonders of his creative power.

THE PLANET URANUS.

This planet, also frequently called after its discoverer, was made known to us by Herschel, who first saw it in March, 1781. Its distance from the Sun is 1,800,000,000 miles; and when nearest the Earth, it is nearly the same distance from us. It moves through its orbit in about 84 years. It is the slowest-moving planet in the system, yet pursues its course at the rate of 1500 miles an hour. It is 110,000 miles in circumference, and 81 times larger than the Earth. Its solar light is 360 times less than ours; yet it is not darker than frequently happens with us in a cloudy day. Its density is nearly equal to that of water. Six satellites are supposed to be connected with this planet; but their periods and other phenomena have not yet been accurately ascertained.

GENERAL REMARKS ON THE PLANETS.

The planets all move from west to east, and nearly in the same plane. They are all opaque bodies, deriving their light from the Sun; they are all spheroidal, approaching the form of an exact globe, with slight unevenness of surface. They have all two motions; one diurnal, around their axes, and one annual, around the Sun. They all present every part of their surface toward the Sun, and they have the alternate change of day and night. They are all connected with the Sun

by the same principle of gravitation. As we know that our Earth is inhabited by thousands of sentient beings, and was created for their accommodation, we may justly conclude that other worlds, associated in the same system, fitted up in nearly the same manner, and acting in obedience to the same great laws, have a similar design, and are, therefore, the abodes of myriads of intelligences not essentially differing from the races on this Earth.

The stupendous scale upon which planets are formed — their mighty masses — their amazing circuits performed in the regions of space — their almost inconceivable velocities — still sink into insignificance, when compared with the enormous bulk of the great central luminary around which they revolve. In order to aid the imagination in its efforts to compass this subject, Dr. Dick makes the following suggestion: —

"There is no point on the surface of the globe that unites so many awful and sublime objects as the top of Etna, and no imagination has dared to form an idea of so glorious and magnificent a scene. The body of the Sun is seen rising from the ocean, immense tracts both of sea and land intervening; the islands of Pinari, Alicudi, Lipari, Stromboli, and Volcano, with their smoking summits, appear under your feet, and you look down on the whole of Sicily as on a map, and can trace every river through all its windings from its source to its mouth. The view is absolutely boundless on every side, so that the sight is every where lost in the immensity.

"Yet this glorious and expansive prospect is comprised within a circle about 240 miles in diameter, and

754 in circumference, containing 45,240 square miles, which is only $\frac{1}{53776608}$ part of the surface of the Sun; so that fifty-three millions, seven hundred and seventy-six thousand landscapes, such as beheld from Mount Etna, must pass before us before we could contemplate a surface as expansive as that of the Sun; and if every such landscape were to occupy two hours in the contemplation, as supposed above, it would require 24,554 years before the whole surface of this immense globe could be in this manner surveyed."

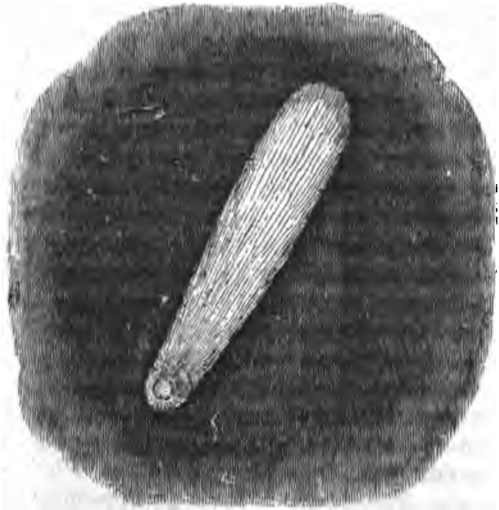
The same writer here quoted, and to whom we are largely indebted in the preparation of this article, says, that "it is owing to the existence of the Sun that our globe is a habitable world, and productive of enjoyment. Almost all the benign agencies which are going forward in the atmosphere, the waters, and the earth, derive their origin from its powerful and perpetual influence. Its light diffuses itself over every region, and produces all that diversity of coloring which enlivens and adorns the landscape of the world, and without which we should be unable to distinguish one object from another. By its vivifying action, vegetables are elaborated from inorganic matter, the sap ascends through their myriads of vessels, the flowers glow with the richest hues, the fruits of autumn are matured, and become, in their turn, the support of animals and of man.

"By its heat, the waters of the rivers and the ocean are attenuated, and carried to the higher regions of the atmosphere, where they circulate in the form of vapor, till they again descend in showers, to supply the sources of the rivers, and to fertilize the soil. By the same agency all winds are produced, which purify the atmos-

phere by keeping it in perpetual motion, which propel our ships across the ocean, dispel noxious vapors, prevent pestilential effluvia, and rid our habitations of a thousand nuisances. By its attractive energy, the tides of the ocean are modified and regulated, the Earth conducted in its annual course, and the moon sustained and directed in her motions. Its influence descends even to the mineral kingdom, and is felt in the chemical compositions and decompositions of the elements of nature.

"The disturbances in the electric equilibrium of the atmosphere, which produce the phenomena of thunder, lightning, and rain, and the varieties of terrestrial magnetism; the slow degradation of the solid constituents of the globe, and their diffusion among the waters of the ocean, may all be traced, either directly or indirectly, to the agency of the Sun. It illuminates and cheers all the inhabitants of the Earth, from the polar regions to the torrid zone. When its rays gild the eastern horizon, after the darkness of the night, something like a new creation appears. The landscape is adorned with a thousand shades and colors; millions of insects awake and bask in its rays; the birds start from their slumbers, and fill the groves with their melody; the flocks and herds express their joy in hoarser acclamations; 'man goeth forth to his work and to his labor;' all nature smiles, and 'the hills rejoice on every side.' Without the influence of this august luminary, a universal gloom would ensue, and surrounding worlds, with all their trains of satellites, would be shrouded in perpetual darkness. This Earth would become a lifeless mass, a dreary waste, a rude lump of inactive matter, without beauty or order."

COMETS.



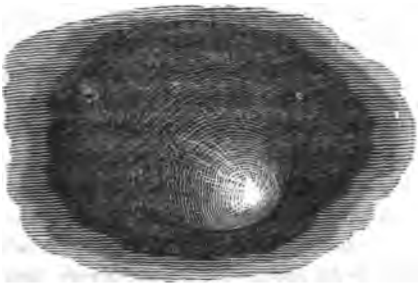
None of the heavenly bodies have been regarded with more interest than the comets, those wandering and mysterious bodies which, in remote ages, were beheld with superstitious terror. They have been imagined to portend war, pestilence, famine, and the death of monarchs; to be the vehicles in which departed souls, released from the care of guardian angels, were transported to heaven; to have been the cause of the deluge; to reënforce the light and heat of the sun; to break up large planets into smaller ones; to change the climate of countries; to introduce epidemic disorders; and, finally, to threaten our globe with total destruction.

A great comet is indeed an object well calculated to impress every beholder with astonishment and awe. Comets have been known with tails extending from the zenith to the horizon, while the disk of the body itself was equal in size to the full moon. The belief which prevailed for a long time with regard to the nature of these bodies, was, that they were meteors of temporary duration, engendered in the atmosphere of the Earth. Some circumstances, certainly, gave a degree of plausibility to this supposition; the suddenness, in many cases, of their appearance and disappearance, the transparency of their tails, and the apparently small density of their bodies. But accurate observations showed that they were far beyond the region of the moon, rendering it clear that they could not be vapors generated in our atmosphere, and giving a strong probability to the opinion maintained of old by the Chaldeans, and supported by Seneca, that they were bodies permanent as the planets of our system, and reappearing at certain intervals, depending on their peculiar orbits.

It is probable that comets are nothing but bodies of gas or vapor, without any solid matter whatever. Stars have been repeatedly seen through their thickest parts. The mechanical effect, therefore, to the Earth, from its collision with a comet, would be no greater than that of a mountain when in contact with a cloud: the result of such a collision would be the mixture of the gaseous matter with the Earth's atmosphere; a permanent rise, perhaps, in the mean height of the barometer; and, if the gaseous matter should condense sufficiently to descend to the lower regions of our atmosphere, some effect upon animal or vegetable exist-

ence, good or bad. The Earth may actually have been many times in the tail of a comet, without having any strong marks of such an accident.

The bodies of comets have varied from 30 to 3000 miles in diameter; some of them have been entirely destitute of tails, and others have exhibited them 100,000,000 of miles in length. They move in narrow, elliptical orbits, travelling to an immense distance out of our system, and at their return approaching, in most cases, much nearer to the Sun than any of the planets. Of three of them the periodical revolution has been ascertained. Encke's comet revolves in



Encke's Comet.

three years and a half; Biela's in six and three quarters; and Halley's in seventy-five years and a half; the last of these made its appearance in 1835. A comet with a tail of uncommon magnitude, but with a nucleus scarcely perceptible, visited us in 1843. The great comet of 1680, when at its perihelion, or point nearest the Sun, was only at the distance of one sixth of his diameter from that great body of fire; it conse-

quently was exposed to a heat 27,500 times greater than that received by the Earth — a degree so intense as to convert into vapor every terrestrial substance with which we are acquainted. One hundred and forty comets have appeared within the Earth's orbit during the last century, which have not again been seen. If a thousand years be allowed as the average period of each, it may be computed, by the theory of probabilities, that the whole number ranging within the Earth's orbit must be 1400. But Uranus being twenty times more distant, there may be no less than 11,200,000 comets that come within the known extent of our system.

The trains of comets are always thrown off in a direction opposite to the Sun. No satisfactory solution of the nature and cause of these has been assigned. The effect is the same as if the nucleus of the comet were a globe of water, and the Sun, in shining through it, cast its refracted rays to a distance beyond.

THE FIXED STARS.

Such is a brief description of the solar system, which, down to the beginning of the present century, comprised within its limits almost the whole of astronomical science. Before this period, the planetary orbits seemed to encircle all the space accessible to the human eye; they had effectively established limits to systematic inquiry; for astronomers had never pushed their researches into remoter depths, having, like the uninstructed multitude, gazed at the farther heavens with vague and incurious glances, content to admire their beauty and confess their mystery. This period,

however, was distinguished by two events which could not have existed in combination without leading to important results. The *telescope*, formerly of very limited range, suddenly assumed a capability of sounding immense profundities of space; and the man in whose hands it attained this new power was possessed of a genius adequate to improve the highest opportunities. The life of Sir William Herschel marks the first and greatest epoch of modern astronomy. He was a discoverer of the first rank: mingling boldness with a just modesty, a thirst after large and general views with a habit of scrupulous obedience to the intimations of existing analogies, he was precisely the man to quit paths which, through familiarity, were common and safe, and to guide us into regions dim and remote, where the mind must be a lamp to itself.

Herschel communicated to the world the first proof that there existed in the universe organized systems besides our own; while his magnificent speculations on the Milky Way, and the constitution of the Nebulæ, first opened the road to the conception that what was called the universe might be, and in all probability is, but a detached and minute portion of that interminable series of similar formations which ought to bear the same name.

But before we pursue this topic farther, it will be necessary to give an account of the FIXED STARS, or that stellar firmament to which the solar system belongs. About 2000 of these stars are visible to the naked eye; but when we view the heavens with a telescope, their number seems to be limited only by the imperfection of the instrument. In one hour Sir William Herschel estimated that 50,000 stars passed

Fixed Stars.

through the field of his telescope in a zone of the heavens two degrees in breadth. It has been calculated that the whole expanse of the heavens must exhibit about 100,000,000 of fixed stars, within the reach of telescopic vision. These stars are classed according to their apparent brightness; and the places of the most remarkable of those visible to the naked eye, are ascertained with great precision and formed into a catalogue. The whole number of stars registered amounts to about 200,000. The distance of the fixed stars is too great to admit of their exhibiting a perceptible disk. With a fine telescope, they appear like mere luminous points. Their twinkling arises from sudden changes in the refractive power of the air, which would not be sensible to the eye if they had disks, like the planets. Thus we can learn nothing of the relative distances of the fixed stars from us, and from one another, by their apparent diameters;

but as they do not appear to change their position during the passage of the Earth from one extremity of its orbit to the other, it is evident that we must be more than 200,000,000 miles distant from the nearest. Many of them, however, must be vastly more remote; for, of two stars that appear close together, one may be far beyond the other in the depth of space. The light of Sirius, according to the observation of Sir John Herschel, is 324 times greater than that of a star of the sixth magnitude.

Nothing is known of the absolute size of the fixed stars; but the quantity of light emitted by many of them shows that they must be much greater than the Sun. Sirius is nearly four times larger, and many stars must be infinitely larger than Sirius. Sometimes stars have been known to vanish from the heavens, and never appear afterwards; the lost Pleiad of classical mythology is one of these. The last disappearance of a star, noted by astronomers, was in 1828. Sometimes stars have all at once appeared, shone with a bright light, and vanished. A remarkable instance of this occurred in the year 125, which is said to have induced Hipparchus to form the first catalogue of stars. Another star appeared near the constellation of the Eagle in 389, and vanished, after remaining for three weeks as bright as Venus. On the 10th of October, 1604, a brilliant star burst forth in the constellation of Serpentarius, which continued visible for a year. A more recent case occurred in 1670, when a new star was discovered in the head of the Swan, which, after becoming invisible, reappeared, and having undergone many variations of light, vanished after two years, and has never since been seen.

In 1572, a star was discovered in Cassiopeia, which rapidly increased in brightness till it even surpassed that of Jupiter; it then gradually diminished in splendor, and having exhibited all the variety of tints that indicate the changes of combustion, vanished sixteen months after its discovery, without altering its position. It is impossible to imagine any thing more tremendous than a conflagration that could be visible at such a distance. It is, however, suspected that this star may be periodical, and identical with those which appeared in 945 and 1264. There are, probably, many stars which alternately vanish and reappear, among the innumerable multitudes that spangle the heavens; the periods of thirteen have already been pretty well ascertained.

Of these the most remarkable is in the constellation of the Whale. It appears about twelve times in eleven years, and is of variable brightness, sometimes seeming like a star of the second magnitude; but it does not always attain the same lustre, nor increase and diminish by the same degrees; it goes through a complete revolution of brightness and obscurity in little less than three days. The cause of the variations in most of the periodical stars is unknown, but it is conjectured that they may be occasioned by the revolution of some opaque body coming between us and them. Sir John Herschel is struck with the high degree of activity evinced by these changes, in regions where "but for such evidences we might conclude all to be lifeless."

Many thousands of stars seem to be only brilliant points; but, when carefully examined, are found to be,

in reality, systems of two or more suns, revolving round each other, or round a common centre. These double and multiple stars are very remote, requiring the most powerful telescopes to show them separately. The motions of revolution of many of these stars round a common centre have been ascertained, and their periods determined with considerable accuracy. Some have accomplished a whole revolution, since their discovery. One of these stars revolves round the other in 1600 years, another in 58. It sometimes happens that the edge of the orbit of a star is presented towards the Earth; it then seems to move in a straight line, and to oscillate on each side of its primary. There are also quadruple stars, and even assemblages of five and six, revolving round each other.

Besides revolutions around one another, some of the binary systems are carried forward in space, by a motion common to both stars, toward some unknown point in the firmament. Two stars in the Swan, which are nearly equal, and have remained at the same distance from each other for above fifty years, have changed their place in the heavens, during that period, between four and five minutes, with a motion which for ages must appear uniform and rectilinear, because, even if the path be curved, so small a portion of it must appear a straight line to us. The single stars, also, have proper motions; our own Sun is supposed to be moving towards a certain point in the heavens.

Though the absolute distance of the fixed stars is still unknown, a limit has been found within which, probably, some of them come. It was natural to suppose that, in general, the large stars are nearer to the

Earth than the small ones; but there is now reason to believe that some stars, though by no means so brilliant, are nearer to us than others which shine with greater splendor. This is inferred from the comparative velocity of their movements. In consequence of the progressive motion of our Sun, and its planets, all the fixed stars have an *apparent* motion, which tends ultimately to mix the stars of the different constellations; but none that we know of moves so rapidly as No. 61 of the Swan; and on that account it is reckoned to be nearer to us than any other,—for an object which we are passing by seems to move more quickly, the nearer we are to it.

This circumstance induced Messrs. Arago and Matthieu to endeavor to determine its annual parallax; that is, to ascertain what magnitude the diameter of the Earth's orbit would have, as seen from the star. They found, by observation, that the orbit's diameter of 190 millions of miles would be seen from the star under an angle of only half a second; whence this star must be at the distance of 420 *millions of times* 190 *millions of miles from the earth!*—a distance which light, flying at the rate of 190,000 miles in a second, would not pass over in less than six years. This is the smallest distance at which the star can be: how much greater its real distance is, it is impossible to say. The apparent motion of five seconds annually, which this star has, seems to us extremely small; but at that distance an angle of one second corresponds to 24 millions of millions of miles; consequently, the annual motion of this star is 120 millions of millions of miles; and yet, as M. Arago observes, we call it a *fixed* star!

The double stars are of various hues, but they most frequently exhibit the contrasted colors. The large star is generally yellow, orange, or red ; and the small star blue, purple, or green. Sometimes a white star is combined with a blue or purple one, and more rarely a red and white one are united. In many cases, these appearances arise from the influence of contrast on our judgment of colors. For example, in observing a double star, when the large one is a full ruby red, or almost blood color, and the small one a fine green, the latter loses its color when the former is hidden by the cross-wires of the telescope. But there is a vast number of instances where the colors are too strongly marked to be merely imaginary. Sir John Herschel observes, as a very remarkable fact, that, although red stars are common enough, no example of a solitary blue, green, or purple one has been produced.

The stars are very irregularly scattered over the firmament. In some places, they are crowded together, in others thinly dispersed. A few groups, more closely condensed, form very beautiful objects even to the naked eye, — of which the Pleiades, and the constellation Berenice's Hair, are the most striking examples. But the greater number of these clusters of stars appear, to unassisted vision, like thin white clouds, or vapor; such is the Milky Way, which, as Sir William Herschel has proved, derives its brightness from the diffused light of the myriads of stars that form it. Most of these stars appear to be extremely small, on account of their enormous distances.

This singular portion of the heavens, constituting part of our firmament, consists of an extensive mass

of stars, the thickness of which is small compared to its length and breadth; the Earth is placed at the point where it divides into two branches, and it appears to be much more splendid in the southern hemisphere than in the northern. Sir John Herschel says, "The general aspect of the southern circumpolar regions, including in that expression 60 or 70 degrees of south polar distance, is in a high degree rich and magnificent, owing to the superior brilliancy and large development of the Milky May, which, from the constellation of Orion to that of Antinous, is a blaze of light, strangely interrupted, however, with vacant and entirely starless patches, especially in Scorpio, near Alpha Centauri and the Cross; while to the north it fades away pale and dim, and is, in comparison, hardly traceable. I think it impossible to view this splendid zone, with the astonishingly rich and evenly-distributed fringe of stars of the third and fourth magnitude, which forms a broad skirt to its southern border, like a vast curtain, without an impression, amounting almost to conviction, that the Milky Way is not a mere stratum, but annular; or, at least, that our system is placed within one of the poorer or almost vacant parts of its general mass! The cluster of which our Sun is a member, and which includes the Milky Way and all the stars that adorn our sky, must be of enormous extent, since the Sun is more than 20 millions of millions of miles from the nearest of them; and the other stars, though apparently so close together, are probably separated from one another by distances equally great."

METEORITES.

If such remote bodies as the fixed stars shone by reflected light, we should be unconscious of their existence. Each star must then be a sun, and may be presumed to have its system of planets, satellites, and comets, like our own; and for aught we know, myriads of bodies may be wandering in space unseen by us, of whose nature we can form no idea, and still less of the part they perform in the economy of the universe. Even in our own system, at its farthest limits, minute bodies may be revolving like the new planets, which are so small that their masses have hitherto been inappreciable, and there may be many still smaller.

Nor is this an unwarranted supposition; many such do come within the sphere of the Earth's attraction, are ignited by the velocity with which they pass through the atmosphere, and are precipitated with great violence on the Earth. The fall of meteoric stones is much more frequent than is generally believed. Hardly a year passes without some instances occurring; and if it be considered that only a small part of the Earth is inhabited, it may be presumed that numbers fall in the ocean, or on the unoccupied part of the land, unseen by man. They are sometimes of great magnitude; the bulk of several has exceeded that of the planet Ceres, which is about 70 miles in diameter. One, which passed within 25 miles of the Earth, was estimated to weigh about 600,000 tons, and to move with a velocity of about 20 miles in a second; a fragment of it alone reached the ground. The obliquity of the descent of meteorites, the peculiar substances of which

they are composed, and the explosion accompanying their fall, show that they are foreign to our system.

Luminous spots have occasionally appeared on the dark part of the moon. These have been ascribed to the light arising from the eruption of volcanoes; whence it has been supposed that meteorites have been projected from the moon by the force of volcanic eruption. It has even been computed that if a stone were projected from the moon in a vertical line, with an initial velocity of 10,992 feet in a second, (more than four times the velocity of a cannon-ball,) instead of falling back to the moon by the attraction of gravity, it would come within the sphere of the Earth's attraction, and revolve about it like a satellite. These bodies, impelled either by the direction of the primitive impulse or by the disturbing action of the Sun, might ultimately penetrate the Earth's atmosphere and arrive at its surface; but it is much more probable that they are asteroids revolving about the Sun, and diverted from their course by some disturbing force; at all events, they must have a common origin, from the uniformity of their chemical composition.

AËROLITES.

Shooting stars and meteors differ from *aërolites* in several respects. Aërolites burst from the clear azure sky, and, darting along the heavens, are extinguished without leaving any residuum except a vapor-like smoke, and generally without noise. Calculations have shown them to be very high in the atmosphere — sometimes even beyond its supposed limit; and the direction of their motion is, for the most part, opposite to the

motion of the earth in its orbit. The astonishing multitudes of shooting stars and fire-balls that have appeared within these few years, at stated periods, over the American continent, and other parts of the globe, warrant the conclusion that there is either a nebula, or that there are myriads of bodies revolving round the Sun, which become visible only when inflamed by entering our atmosphere.

One of these nebulæ, or groups, seems to approach close to the Earth, in its annual revolution, on the 12th or 13th of November. On the morning of the 12th of November, 1799, thousands of shooting stars, mixed with large meteors, illuminated the heavens, for many hours, over the whole continent of America, from Brazil to Labrador; they were observed even in Greenland and Germany. Meteoric showers were seen off the coast of Spain, and in Ohio, on the morning of the 13th of November, 1831. In 1832, during many hours of the morning of the 13th of November, prodigious multitudes of shooting stars and meteors fell at Mocha, on the Red Sea, in the Atlantic, in Switzerland and England.

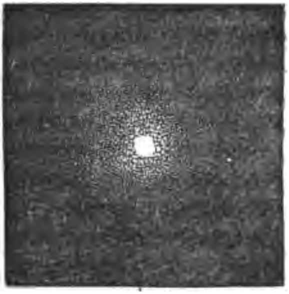
But by far the most splendid meteoric shower on record was in 1833. It began at nine o'clock in the evening of the 12th of November, and continued till sunrise the next morning. It extended from the great lakes of Canada, southward, to Jamaica, and from the 61st degree of longitude in the Atlantic, westerly, to the 100th degree in Central Mexico. Shooting stars and meteors, of the apparent size of Venus, Jupiter, and even the full moon, darted in myriads towards the horizon, as if all the stars in the heavens had started

from their spheres. Those who witnessed this grand spectacle were surprised to see that every one of these luminous bodies, without exception, moved in lines which converged to one point in the heavens. None of them started from that point; but their paths, when traced backward, met in it like rays in a focus, and the manner of their fall showed that they descended from it in nearly parallel straight lines. The most extraordinary part of the phenomenon is, that this radiating point was observed to remain stationary, in the constellation Leo, for more than two hours and a half, — which proves the source of the meteoric shower to be altogether independent of the Earth's rotation. Other observations showed it to be far above the atmosphere.

As all the circumstances of the phenomenon were similar, on the same day, and during the same hours, in 1832, and as extraordinary flights of shooting stars were seen at many places, both in Europe and America, on the 13th of November, 1834, and the two following years, proceeding also from a fixed point in the constellation Leo, it has been conjectured, with much apparent probability, that this nebula, or group of bodies, performs its revolution round the Sun in a period of about 182 days, in an elliptical orbit, and that its greatest distance from the Sun is about 95,000,000 of miles, which brings it in contact with the Earth's atmosphere.

NEBULOUS STARS.

We are now about to introduce to the reader's notice the most wonderful discovery ever made in the science of astronomy, — namely, a planetary system *in the process of formation*, or a chaos of matter gradually gath-



ering into the shape of suns with their attendant worlds! Certain dim spots, or diffused luminous patches, in the heavens, have long been known to astronomers by the name of *nebulæ;* but their phenomena were looked upon as inexplicable, and regarded as barren marvels, until Sir William Herschel completely surveyed them all, studied their curious relations, and formally presented his views concerning their probable nature. These nebulæ are of two sorts, planetary and stellar. In the former, we behold a starlike body, surrounded with a luminous atmosphere, which the strongest telescopes are unable to resolve into separate stars, but which, under every magnifying power, still continue to present the appearance of a vague film.

Sir John Herschel says of one of them, in Orion's sword, "I know not how to describe it better than by comparing it with the curdling of a liquid, or to a surface strewed over with flocks of wool, or to the breaking up of a mackerel sky, when the clouds begin to assume a linear appearance. It is not very unlike the

mottling of the sun's disk, only the grain is much coarser and the intervals darker, and the *flocculi*, instead of being round, are drawn into little wisps. They present, however, no appearance of being composed of stars, and their aspect is altogether different from those of resolvable nebulæ. In these we fancy, by glimpses, that we see stars, or that, could we strain our sight a little more, we should see them; but the former suggest no idea of stars, but rather of something quite distinct from them.

"In reference to the great nebula in the girdle of Andromeda, there are grounds for a similar conclusion. So that we have this novel and most singular matter not only surrounding stars, and enveloping them as an immense *chevelure*, but existing also isolated, and in various conditions, from the shape of perfect diffusion, to that where, as in Andromeda, it shows a central nipple, or an apparent point of condensation. It is, perhaps, in its separate and independent form that it fills us with most astonishment. The profusion with which it is distributed, in this form, in both hemispheres, and, indeed, through all the heavens, would imply that it fulfils, or is pressing to fulfil, some important function in the material economy."

This strange fluid, a self-luminous, phosphorescent, material substance, exists in a great variety of forms, but generally in a globular shape, and in all varieties of density. Some of the masses are only a thin milky patch, of equal tenuity in every part; in others, there is a slight condensation toward the centre: this condensation augments, till, at length, we behold a distinctly-formed star, surrounded by a nebulous atmosphere.

The inference is irresistible, that they are masses of chaotic matter, in a highly diluted or gaseous state, gradually subsiding, by the mutual gravitation of their particles, into stars and sidereal systems. This is the hypothesis of Laplace with regard to the origin of the solar system, which he conceived to be formed by the successive condensations of a nebula whose primeval rotation is still maintained in the rotation and revolution of the Sun, and all the bodies of the solar system, in the same direction. Even at this day, there is presumptive evidence, in the structure and internal heat of the Earth, of its having been at one period in a gaseous state, from an intensely high temperature.

The question will naturally occur here, How can such stars as we see come out of these nebulous masses? and can any star, thus produced, resemble in character the known individuals of our heavens? To a certain extent this inquiry has been answered, ingeniously and satisfactorily. It is manifest that the orbs arising out of a nebula would be subject to a motion of rotation on an axis, as the Sun is, and, in all probability, the fixed stars are. The confluence of particles toward a centre of attraction would, in general, if not universally, produce a whirlpool, of which an illustration is extant in the confluence of almost all differently-flowing streams. A rotary motion once communicated, its velocity would increase with the process of condensation. The resulting orbs, then, would rotate; and as the circumstances of their origin would vary, they would rotate in varying times. The phenomenon of the double stars is also explained here. The whirlpool motion of the original nebula would in-

evitably cause an orbitual revolution of binary and more complex systems. A diffused nebulosity is sometimes seen broken up into two or more round nebulæ, yet hardly separated. If these individual masses rotate, or are like whirlpools, they must act on each other as wheels; the result may be illustrated by a very familiar example. Walk along the side of a river, and notice the little moving eddies caused in such multitudes by the interference of currents from the unequal sides of the stream; follow these small eddies for a moment, and observe how, on being whirled down the stream, they come into contact or proximity to each other; that instant they *form a system*, the one revolving round the other, or rather both revolving round some intermediate point.

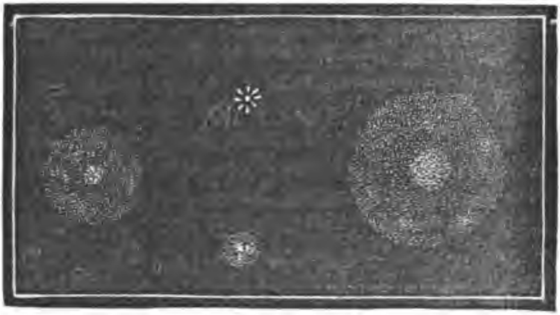
The Sun, and, probably, the other orbs, are attended by planets; and it is, perhaps, the most interesting part of the whole speculation, to follow Laplace in his account of the gradual formation of these minute circumstellar bodies from the bosom of the condensing nebula. In any given state of the rotating mass, the outer portion, or ring, is in the condition of having its centrifugal force exactly balanced by its gravity. The rotation increasing in rapidity in consequence of the progressing condensation, the mass of the nebula will abandon this outer ring of matter, which may afterwards continue to circulate about the star. Imagination may conceive several zones of vapor thus successively abandoned, and moving, with velocities corresponding to their position, around the Sun, or central nebulous mass. The particles of such rings might condense into a solid or liquid substance; but, unless the

formations were originally uniform in all their parts,—an improbable hypothesis,—they would not condense as rings. We have, in fact, only one example of such a circumstance in the rings of Saturn,—a phenomenon altogether invaluable in illustration of the primary condition of our system. In most cases, these zones would divide, and form several masses, circulating around the Sun. The same process, in the mean time, would be going on with regard to the planets, in the formation of their satellites.

Distinct evidences of the originally nebulous state of the solar system are not wanting. There is a phenomenon called the zodiacal light, which may be seen in the twilight of morning and evening, in the neighborhood of the Sun, in the shape of a pyramid, or cone, rising above the horizon, and considerably inclined on one side. It appears to extend beyond the orbit of Venus, and is regarded as a portion of the original nebular mass of our system not yet condensed. The comets, moreover, are evidently nebulous bodies, and most of them are strangers to our system, or rather, fortuitous visitants. This fact merely indicates that we must seek their origin in the external spaces, and we find it in those masses of nebulous fluid with which they are intimately connected by constitution, and whose formerly questionable existence they render visible and almost tangible. How interesting the change which passes over the whole aspect of these wandering bodies, when viewed in their true position, not as anomalies, not as monstrous and disturbing intruders into a system with which they are not connected by any harmonizing ties, but as outposts of a mighty sys-

tem, which vastly extend our notions of that amount of formless matter existing among the stellar intervals, and which are themselves in progress toward a more perfect organization!

In illustration of the process of the formation of stars and systems from nebulæ, the following cut speaks to the eye, and is more valuable than pages of description. Each figure in this plate is the representation,



Stars and Systems forming from Nebulæ.

not of an individual, but of an extensive class; and it would seem that a series so well marked, so striking in its aspects, must indicate the presence and influence of a great law. From absolute vagueness to distinct structure, and then on to the formation of a defined central nucleus, the nebula seems growing under our eye! "We look," says Laplace, "among these objects as among the trees of a forest; their change, in the duration of a glance, is undiscoverable: yet we perceive that these are plants in all different stages; we see that these stages are probably related to each other in the order of time, and we are irresistibly led

to the conclusion that the vegetable world, in the one case, and the sidereal world in the other, exhibit, at one instant, a succession of changes requiring time, which the life of man, or the duration of the solar system, may not be sufficient to trace out in individual instances."

There is a creature called the ephemeron, whose life is limited within a mere point of time; in a single day it dances out its existence in the sunbeam. That creature lives in the presence of all the phenomena of vegetable growth; it may see trees, it may see flowers; but how could it, or its generations, actually observe their progressive development? In relation to the nebulæ, man is but an ephemeron. Fifty lives succeeding each other, and of a length to which individuals often attain, would reach backward beyond the recorded commencement of his race; and, in the mutability of things, fifty more may close its career. Thus no more than what one hundred ephemera can see of the progress upward of the majestic pine, will man, perhaps, ever actually behold of the changes of the nebulæ.

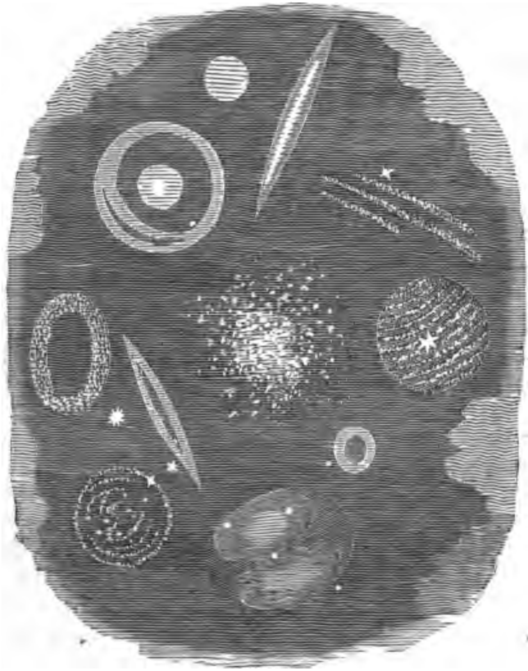
Yet, after all, where is the intrinsic difference between the formation of a system of worlds, and the growth and progress of the humblest leaf from its seed to its intricate and most beautiful organization? That which bewilders us is not any intrinsic difficulty or disparity, but a consideration springing from our own fleeting condition. We are not rendered incredulous by the *nature*, but overwhelmed by the *magnitude*, of these creations; our minds will not stretch out to embrace the periods of this stupendous change. But time is illimitable, and we are speaking of the operations, and tracing the footsteps, of a Being who is above all time; we are contemplating the energies of that almighty

mind, to whose infinite capacity a day is as a thousand years, and the lifetime of the entire human race but as the moment which dies with the tick of the clock that marks it — which is heard and straightway passes.

THE FIRMAMENTAL SYSTEMS.

Notwithstanding the amazing extent of the worlds, and systems of worlds, we have described, they do not constitute the whole universe, but only a very small part of it. Countless *firmaments*, or clusters of stars, distinct from ours, and at an immense distance from it, exist, sustaining an independent position, as individual constituents of creation. We have already carried our researches into what seemed the infinity of space; but we must now go forth into far deeper infinity among these firmaments, and ascertain their character.

In the intervals between the stars of our own system, and at an immense distance beyond them in the depths of space, many clusters of stars may be seen, like white clouds, or round comets without tails. When examined with proper instruments, they convey the idea of a globular space, insulated in the heavens, and filled full of stars, constituting a family, or society, apart from the rest, subject only to its own internal laws. The number of these masses is very great. In the northern hemisphere, after making all allowances, those whose places are fixed cannot be fewer than 1000 or 2000; and we may form some idea how plentifully they are distributed, by recollecting that this is at least equal to the whole number of stars which the naked eye beholds at once on any ordinary night.



Various Forms of Nebulæ.

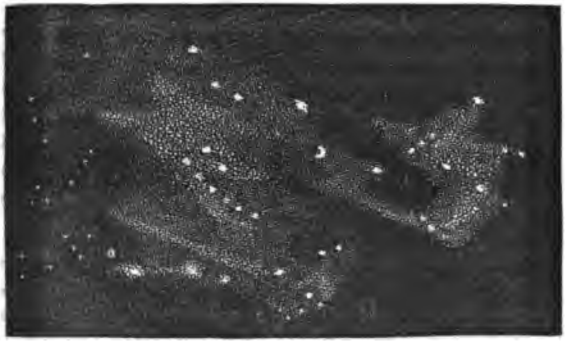
To attempt to count the stars in one of these clusters, would be a vain task; they are to be reckoned not by hundreds, but by thousands. On a rough computation, it appears that many of them must contain 10 or 20,000 stars, compacted and wedged together in a globular space, whose area is not more than a tenth part of that covered by the moon; so that its centre,

where the stars are seen condensed, is one blaze of light. If, as we have every reason to believe, each of these stars be a sun, and if they be separated by intervals equal to that which separates our Sun from the nearest fixed star, the distance which renders the whole cluster barely visible to the naked eye, must be so great, that the existence of this splendid assemblage can only be known to us by light which must have left it a thousand years ago!

These clusters have a variety of shapes — some of them most singular and fantastic. In many of them, individual stars are distinctly defined. As they become more remote, the intervals between the stars diminish, and the light grows fainter. In their faintest stellar aspect, they may be compared to a handful of fine, sparkling sand, or, as it is aptly termed, *star-dust.* Beyond this we see no stars, but only a streak, or patch, of milky light. Vast multitudes of these are so faint as to be with difficulty discerned at all, till they have been for some time in the field of the telescope, or are just about to quit it. Occasionally, they are so vague, that the eye is conscious of something, without being able to define what it is; but the unchangeableness of its position proves that it is a real object.

The central cluster of stars, in the preceding cut, is a good specimen-object, as it is a representative, or type, of a very large class. Notwithstanding the partial irregularity of its outline, it seems almost a spherical mass, in which, with a degree of greater compression toward the centre, the stars are pretty equally and regularly diffused, so that, to the inhabitants of worlds near its central regions, its sky would spangle

uniformly all around, and present no phenomenon like the Milky Way, in ours. Others of the spherical clusters show a much greater compression about the centre — a circumstance which would manifestly augment the proportionate number of orbs of the first magnitude in view of those living within the compressed portion, and thus render their visible heavens inconceivably brilliant. Firmaments, however, are by no means confined to the spherical form, as we have already remarked. In the southern hemisphere, a phenomenon, known by the name of the Magellanic Clouds, long excited the wonder of all beholders. These clouds have been found to be immense nebulæ, or firmaments, of a singular shape. The following is a representation of one of them.



This nebula, according to the description of Sir John Herschel, who spent some time at the Cape of Good Hope, in astronomical researches, "is a congeries of clusters of irregular form, globular clusters, and nebulæ of various magnitudes and degrees of condensation,

among which is interspersed a large portion of irresolvable nebulæ, which may be, and probably is, star-dust, but which the powers of the twenty-feet telescope show only as a general illumination of the field of view, forming a bright ground, on which the other objects are scattered. Some of the objects in it are of very singular and incomprehensible forms — the chief one especially, which consists of a number of loops, united in a kind of unclear centre or knot, like a bunch of ribbons disposed in what is called a true-love knot. There is no part of the heavens where so many nebulæ and clusters are crowded into so small a space as this cloud!"

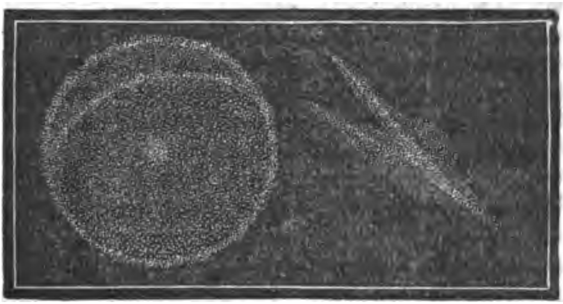
But it is when we arrive among the almost bewildering multitudes of unresolved systems, that we are most forcibly struck by the variations of their fantastic shapes. The unresolved clusters being at depths much profounder than the sites of the others, the sphere appropriated to them is, of course, of larger radius, and far more capacious, so that there is room for greater numbers, and also a more wonderful display of variety. The accompanying sketch exhibits a few of these

curious shapes. The annular form sometimes occurs; one fine instance of it is in the constellation of the Lyre. The oblong sharp hoop, represented in the preceding cut, is probably likewise a large ring, but appearing sharp in consequence of its oblique position with regard to us. How utterly different from ours must be the aspects of the sky to the inhabitants of such a firmament! The space within the ring is nearly a blank, but not perfectly so, a very thin mass of light spreading over it; so that, to the eye of a spectator placed within the space, the sides will appear nearly an utter blank, while the other part of the heavens will be engirdled with a zone of the most dazzling lustre.

One of the most singularly-shaped clusters is the large object in the preceding page. It has the shape of an hour-glass, or dumb-bell; the two connected hemispheres, as well as the connecting *isthmus*, being bright and beautiful, manifesting a dense collection of stars in those regions, while the oval is completed by two spaces, which do not transmit a greater quantity of light, nor indicate the presence of a larger number of stars, than the comparatively vacant interior of the ring above described. We are lost in mute astonishment at these endless diversities of character and form. But in the apparent aim of the things near and around us, we may perhaps discern some purpose which such variety may serve. It seems the object, or result, of known material arrangements, to produce every variety of creature; and perhaps it is one end of this wonderful evolution of firmaments of all orders, magnitudes, and forms, that there, too, the law of variety may prevail,

and room be found for unfolding the whole riches of the Almighty.

Of all these wonderful exhibitions, there is no one more singular than what we are about to describe. Although the telescope has not yet enabled us to lay out the plan of our own cluster from *interior* surveys, it exhibits what seems to be its very picture hung up in external space. The accompanying cut represents a nebula resting near the outermost range of telescopic



observation, which is the *fac simile* of the system to which we belong! A double representation is given, one of them showing it in a broadside, and the other in an edgewise view. It has its surrounding ring, of the precise form which we have been inclined to attribute to our Milky Way. It adds much to the interest with which we contemplate this cluster, that the inhabitants there must see our system precisely as we see theirs—namely, sideways; so that we behold objects of the same aspect when we look at each other. Singular affinity of forms! What link, what far-reaching sympathy,

can connect these twin masses, — that unfathomed firmament and ours! What virtue is there in a shape so fantastic, that it should be thus repeated? — or what is the august law, exerting its force at the opposite extremities of space, which has caused these corresponding shapes to come into being?

Struck with an absorbing and most natural astonishment, we soon start the inquiry, *What are these clusters doing?* What is their internal condition? What are their mechanisms? And what the nature and affections of the bodies which compose them? Here we approach the region of clouds and doubt; the solid ground of fact and observation begins to fail us. Yet we are not without warrant in pronouncing that these vast masses are not grouped together by chance, or at random, but that every such union of stars indicates law and system. The only light we find, among these immense spaces, is a welcome gleam of evidence that nature there is also uniform, since the simpler firmaments manifest, by their shapes, the prevalence of an *internal attractive power*. Notwithstanding the fantastic forms which sometimes occur, the round or globular structure is the general or favorite one; and in most of these round clusters there is also a strongly-marked increase of light towards the centre, much more than would arise from the circumstance of the eye then looking through the deepest part of the group, and thereby seeing, at once, the greatest number of its stars. This phenomenon decidedly indicates *compression*, in a greater or less degree; nor is it confined to masses having the perfectly spherical figure. "There are besides," says Sir William Herschel, "additional

circumstances, in the appearance of extended clusters and nebulæ, which very much favor the idea of a power lodged in the brightest part. Although the form of these be not globular, it is plainly to be seen that there is a tendency to sphericity, by the swell of the dimensions the nearer we draw towards the most luminous place — denoting, as it were, a *course, or tide, of stars*, setting towards a centre. And if allegorical expressions may be allowed, it should seem as if the stars, thus flocking towards the seat of power, were stemmed by the crowd of those already assembled, and that while some of them are successful in forcing their predecessors sideways out of their places, others are themselves obliged to take up lateral situations, while all of them seem eagerly to strive for a place in the central swelling and generating spherical figure."

Here another grand field for contemplation is opened. Even the heavens are not stable! These globular masses, at least, are in process of growth, are *ripening;* they are congregating together toward that nucleus round which a new order of things is slowly growing up, and where, perhaps, a mighty orb, whose dimensions almost affright the imagination, is preparing for its birth. And this process is, after all, only the prolongation of the condensing of a simple nebula. Already, some few of its particles have come together and formed its secondary stage; and now that secondary stage, which we term a firmament, is passing into a third, where all the dispersed atoms will be gathered together, and lodged at the centre of the mass!

Our own firmament presents appearances which not only sustain the foregoing conclusions, through a strong

analogy, but point the way to still bolder thoughts. The Milky Way has been already described as a ring, for the most part isolated, in which the stars are very dense, and where the aggregating power has drawn them from the general mass, and, by some curious operation, compressed them into a crowded girdle. But neither is this girdle uniform. It is divided into groups, chiefly inclining to the spherical form, and separated from each other by dark spaces, like *wrinkles of age.* Sir William Herschel counted no less than 225 such groups, or subordinate clusters, within the portion of it which he examined; and as all these were of a kind to mark the action of gravity, he inferred the existence of a clustering power, drawing the stars of it into separate groups,—a power which had broken up the uniformity of the zone, and to the irresistible force of which it was still exposed. "Hence," says he, in one of those bold moments in which he fearlessly traversed the infinities alike of past and future, "may we be certain that the stars will be gradually compressed through successive stages of accumulation till they come up to what may be called the *ripening period* of the globular cluster, and total insulation; from which it is evident that the Milky Way must forcibly be broken up, and cease to be a stratum of scattered stars. We may also draw an important additional conclusion from the gradual dissolution of the Milky Way; for the state into which the incessant action of the clustering power has brought it, is a kind of *chronometer*, that may be used to measure the time of its past and present existence. And although we do not know the rate and going of this mysterious chronometer, it is, nevertheless,

certain, that, since a breaking up of the parts of the Milky Way affords a proof that it cannot last forever, it equally bears witness that its past duration cannot be admitted to be infinite." Here is a vision of unfathomable changes — of the solemn march of the majestic heavens from phase to phase, obediently fulfilling their awful destiny.

If the aggregation of the stars in the Milky Way still goes on, as it prognosticates, for ages, the clusters which now, with some intermission, form its ring, will become isolated, and appear in the character of separate systems. But if this may happen in future time, may not something similar have happened in time past? The aspect of the heavens affords much to countenance this supposition. We can point out, for instance, a cluster of a remarkably irregular form, very narrow in one direction, and surprisingly ragged in the edges. Can it be possible that masses of stars have been torn away from it in certain directions, so that its thinness may simply indicate that, through the action of some irresistible cause, parts of it had there ripened sooner? Singular to relate, it is precisely towards these thin sides, and almost immediately beyond them, that the vast mass of *neighboring* isolated clusters is found — clusters all spherical, and grouping together in extraordinary proximity.

But these operations are, perhaps, only types of what may have occurred on a far more majestic scale. The separate firmaments which our telescopes have discovered show, even more emphatically than the groups in the Milky Way, the efficacy and progress of a clustering power. May not *they* all have come originally

from one homogeneous stratum, or mass of stars, — so that their present isolation, their separation, and various grouping, are only the measured movements of the clock, the gigantic steps of the hand, by which Time records the days of the years of the existing mechanism of the universe? Stupendous the conception, that these great heavens — the heavens which we have deemed a synonyme of the Infinite and Eternal — are nothing else, after all, than one aspect in which matter is destined to present itself, and that their history is like the birth, life, death, and dissolution, of the fragile plant! If this, indeed, be true, — and the idea can be supported by many probabilities, — how immense the sphere of real existence! How little can we ever know of it! at least, how much must be referred to that higher state of existence, an expected eternity of sublime contemplation!

PROPERTIES OF MATTER.

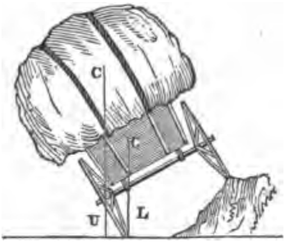
MATTER is the general name which has been given to every species of substance, or thing, which is capable of occupying space, or which has the qualities of length, breadth, and thickness; consequently, every thing which can be seen or felt, is said to be matter. In describing the properties of matter, it must be understood that they do not apply to the masses, or substances, commonly met with, but to the uncompounded or primitive materials of which such substances are formed. These original component parts, of which all substances

are made up, are styled simple matter, elementary principles, or, simply, elements. The ancients, as is well known, supposed that there were but four elements, or simple substances—Fire, Air, Earth, and Water; and out of these, or certain combinations of them, all the substances in nature were formed. But modern chemistry, as we shall show hereafter, has discovered that these elements are by no means simple, but capable of being decomposed.

Every solid body, or dense mass, possesses what is called a *centre of gravity*, which is the point upon or about which the body balances itself, and remains in a state of rest, or equilibrium, in any position. The centre of gravity may be described as a point in solids which always seeks its lowest level. In round, square, and all regularly-shaped bodies, of uniform density in all their parts, the centre of gravity is the centre of these bodies. When a body is shaped irregularly, the centre of gravity is the point upon which the body will balance itself, and remain in a state of rest.

The *line of direction* is an ideal line drawn from the centre of gravity of any body, and passing to the ground in a direction perpendicular to the earth's surface. When this line falls within the base of the body, or the part upon which it stands, the body will keep its position; but if the line falls without the base, the body will fall, or overturn. By keeping this principle in view, stability and safety will generally be secured in the erection of works of art,—such as houses, monumental edifices, spires, steeples,—as well as in the lading of wagons, and carts, and other vehicles. In every instance, the base ought to be sufficiently large to

admit of the line of direction falling within it. Through ignorance of this principle, and from want of experience, we often see stage-coaches and wagons laden in such a manner that their centre of gravity is liable to too great a change of position, and that they are overturned, to the personal injury, and even loss of life, of the passengers. In the annexed cut, a loaded vehicle



is represented as crossing the side of a hill, which has raised one wheel above the level of the other wheel, so as to incline the body of the vehicle very considerably from the horizontal. The centre of gravity is represented in two different positions; a lower one with the line of direction L C, and a higher one with the line of direction U C. If there had been no load upon the vehicle, the line of direction would have remained at L C; and as it falls within the wheel, or base, the vehicle would have maintained its balance. But if the wagon had been laden, the centre of gravity would have been raised, and, the line of direction U C consequently falling without the wheel, the vehicle must overturn.

An exception to this rule occurs in the case of

skaters, in making their circular turns on the ice, in which they bend, or lean, greatly beyond the perpendicular position, without falling. This is owing to the contrary effects of *centrifugal force*, a notice of which will next engage our attention. All bodies, in flying round a centre, have a tendency to proceed in a straight line; and this principle of motion is termed *centrifugal force*. Examples of this tendency are very familiar to our observation. When we whirl rapidly a string with an apple at one end of it, and suddenly allow the apple to fly off, it proceeds at first in a straight line, but gradually falls to the earth. We see many applications of this principle every day; great use is made of it, also, in manufactures and machinery. In the grinding of corn, and in the making of pottery and glass, it saves much trouble and expense. If a skater or equestrian should stand perfectly upright while turning corners and describing circles, he would inevitably fall on his side, being overturned by the centrifugal force. But by leaning inwards, the centrifugal force is counteracted by gravity, and this forms a support to his overhanging body.

Thus, centrifugal force is the tendency to fly off in a straight line from motion round a centre; and the power which prevents bodies from thus flying off, is called the *centripetal*, or *centre-seeking* force. In the case of the apple, the centrifugal force is the impetus given to the apple, which would make it fly away, if the string were to break. The centripetal force is the string, which prevents it from flying away, and gives a circular direction to its motion.

It is upon the mutual action of these two forces that

the stability of the solar system depends. If the tendency of the earth and planets to gravitate towards the sun were removed, they would fly off from it in perfectly straight lines, and never return; and if it were not for the centrifugal force, which is a result of their circular motion, they would rush to the very body of the sun; and, in either case, the harmony of the solar system would be entirely overturned.

Bodies, on being projected by any impulsive force, are called *projectiles*, and are observed to pursue a curvilinear and bent line of direction in their motion. The bending from the straight line is produced by the force of gravity, and "*the change is proportional to the impressed force.*" A ball fired from a cannon, a stone thrown from the hand, and water spouted from a confined vessel, furnish familiar examples of curvilinear motion.

The investigation of the paths which bodies describe when thrown, and of many things relating to their motion, results in certain definite rules, called the *laws of projectiles.* Skilful generals, in bombarding towns, and attacking vessels, at safe distances, take great advantage of their knowledge of these laws.

There are many very interesting circumstances connected with this subject, which our space will not allow us to notice.

Notwithstanding the various substances which nature offers to our observation may differ essentially in touch, weight, and appearance, yet the elements of which they are composed all possess the common, mechanical properties of matter, which properties are five in number —namely, 1. The particles of matter are *solid*, and

occupy space. 2. They are *infinitely divisible.* 3. They are *impenetrable.* 4. They possess mobility, but are *inert.* 5. They universally *attract* and are attracted. The first of these properties needs no proof; for the definition already given of matter is, that it has length, breadth, and thickness; and nothing can have these properties without occupying space, and being solid. These characteristics exist in all matter, although at first they may be invisible: thus air, which cannot be seen, is matter; for if a glass tube, open at both ends, have its upper end closed by the finger while its lower one is immersed in a jar of water, it will be seen that the air is material, and occupies its own space in the tube, for it will not permit the water to enter it till the finger is removed, when the air will escape, and the water will rise to the same level inside, as outside, of the tube.

The second property of matter is, that it is infinitely divisible; or, in other words, that the original component parts, or elementary particles, of which all things are formed, are small beyond conception. Thus, if marble, or any other brittle substance, be reduced to the finest powder which human art can produce, its original particles will not be bruised or affected—since, if this powder be examined by a microscope, each grain will be found to be a solid stone, similar in appearance to the block from which it was broken, and of course, if we possessed suitable implements, would admit of being again subdivided, or reduced to a still finer powder. If a single grain of copper be dissolved in about fifty drops of nitric acid, and the solution be afterwards diluted with about an ounce of water, it is evident that

a single drop of it must contain an almost immeasurably small portion of copper. Yet, so soon as this comes in contact with a piece of polished iron, or steel, that metal will become covered with a perfect coat of copper, which shows how infinitely the copper can be divided without any alteration in its texture. Gold becomes so attenuated under the hammer, in forming it into gold leaf, that the 500,000th part of a grain is visible to the naked eye, or the 5,000,000th part through a microscope magnifying but ten times. It has been calculated that a pound of gold would gild a silver wire 24,000 miles in length, or capable of encompassing the globe. But the wonders of art sink into nothing when compared to those of nature. Leewenhoek, the celebrated microscopic observer, affirms, that he has counted two millions of animalculæ in a portion of the roe of a codfish no larger than a common grain of sand.

That matter is infinitely divisible, admits also of demonstration on mathematical principles; for if a particle of matter, however small, be laid on a plane surface, it must necessarily have an upper and an under part, or a part which touches, and a part which does not touch, the plane.

The third property of matter — its impenetrability — seems to have been adopted by Nature, that her works might be everlasting, and incapable of wearing out; for, although matter, in many instances, seems to disappear, as in the cases of burning and evaporation, yet chemistry distinctly proves that it is incapable of annihilation, and that the original particles, in all cases, still

exist, though, by a change of arrangement, they are made to assume a different appearance.

Mr. Olmstead, speaking of this subject, says, "In all the changes which we see going on in bodies around us, not a particle of matter is lost; it merely changes its form; nor is there any reason to believe that there is now a particle of matter either more or less than there was at the creation of the world. When we boil water, and it passes to the invisible state of steam, this, on cooling, returns again to the state of water, without the least loss. When we burn wood, the solid matter of which it is composed passes into different forms — some into smoke, some into different kinds of airs or gases, some into steam, and some remains behind in the state of ashes. If we should collect all these various products, and weigh them, we should find the amount of their several weights the same as that of the body from which they were produced; so that no portion is lost. Each of the substances into which the wood was resolved, is employed, in the economy of nature, to construct other bodies, and may finally reappear in its original form. In the same manner, the bodies of animals, when they die, decay, and seem to perish; but the matter of which they are composed merely passes into new forms of existence, and reappears in the structure of vegetables, or of other animals."

Even substances which appear soft, such as air and water, appear hard when submitted to proper examination. Thus a quantity of water, falling in an open tube, seems to exert no particular force, on account of the resistance which it meets with from the air; but if the

air be previously removed by the air-pump, there will be no resistance, and the water will sound like the falling of shot, or stones. This is called a water-hammer. Air differs from water in being elastic, but its solidity is shown by the difficulty of compressing a bladder filled with it.

The fourth property of matter — namely, that it possesses mobility, but is inert — is the constant object of our observation. By mobility is meant, that it may always be moved if a sufficient force be applied to overcome its weight, or *vis inertiæ:* and by being inert, we understand that it is inactive, or indifferent to either rest or motion, yet admits of either, but always exerts a power to remain in that state in which it is found. For instance, when a person is riding on horseback, and the horse suddenly stops; or is in a carriage, or boat, which is impeded by striking against an obstacle; the person is thrown forward, from his insensible endeavor to remain in the state of motion in which he then was. That this is the case with inanimate as well as animate nature, will appear by giving a sudden push to a bowl of water, when the water will flow over on the side on which the impulse was given; but if once the bowl is put in motion, and then suddenly stopped, it will flow over on the opposite side. Numberless other instances may be found, in the difficulty of putting heavy bodies, such as ships, loaded wagons, &c., into motion. From this property of matter, if a stone or any inanimate mass is undisturbed, it will remain forever motionless; and when once put into motion, would continue in it, and move forever, were it not prevented by the resistance of the air, and by friction.

Attraction is the fifth property of matter, and exists in every individual particle. All matter attracts, and is attracted, in proportion to its quantity; therefore, all things upon the earth incline, or are drawn, towards its centre, because the earth is the largest mass of matter in their immediate vicinity. There are several kinds of attraction — distinguished by the names of cohesion and gravitation — magnetic, electric, and elective attraction, or affinity. These, in their general effects, — with the exception of the last, — appear nearly similar, although they depend upon different circumstances.

The attraction of cohesion is that power which unites the separate or individual particles of matter, and forms them into masses, or bodies. This attraction, in general, does not extend to any sensible distance from the body; and hence, when the parts of any substance are separated or broken, it is difficult to unite them. But if they can be brought into sufficiently close contact, this attraction operates, and they are joined. On this principle, two pieces of hot iron may be hammered together and united. A plate of lead, and one of tin, passed together through a flatting-mill, become combined into one plate of metal. Glues, cements, and solders, act in the same manner, upon the respective substances to which they are applied, by stopping up the pores, or interstices, and making the contact more perfect. The agency of this principle is shown by pressing two lead planes together, when they will adhere so firmly as to require considerable force to separate them; and the increasing ratio of this attraction, as bodies approach each other, is very well shown by floating two corks on the surface of the water, when they will run together

with an accelerated motion. The power which holds all things to the earth's surface is this same attraction; but when spoken of as applying to worlds, it is called the attraction of gravitation.

As the attraction of cohesion is common to all matter, it would appear that particles of every description must indiscriminately cohere and stick together, and form substances; and, consequently, that an infinite variety of compounds would be found in nature, with almost an impossibility of any two of them being alike. Such would undoubtedly be the case, were it not for that modification of attraction called affinity, or elective attraction: this, however, belongs rather to chemistry, than to the present division of our subject. By this power, the general effects of cohesion are restrained, and only one particular species of matter will unite with another, unless, in some cases, by the interposition of a third or fourth material; in consequence of which, only a definite number of natural substances are formed, and the same thing always appears with nearly similar characteristics.

Capillary attraction is that species of attraction by which fluids are raised in small tubes, and is a modification of the attraction of cohesion. If a capillary tube, or tube of very small diameter, be immersed in fluid, that fluid will rise to a certain height in it proportionate to the size of its base, rising highest in the narrowest tubes. This depends on the cohesive attraction exerted by the sides of the tube, and accounts for sap rising in the pores or tubes of vegetables. The increasing force of this attraction with the diminished size of the tube, is beautifully shown by two

square glass planes, touching at one edge, and separated at the opposite one by a wedge. On immersing these in water, and then raising them out of it, a portion of the water will be retained in that mathematical curve denominated an hyperbola. Capillary attraction also causes fluids to rise in sponges, sugar, sand, and other porous bodies, as soon as they come into contact with them.

The comparative density of bodies — by which is meant their variation in weight while of the same dimensions — most probably depends upon their original molecules, or atoms, being of such forms, and so disposed, as to admit of their coming into more or less close contact. Thus a greater number of particles will pack, or lie, in any given space, if their forms are regular, than could do so were they irregular. For example, it may be supposed that 1,000,000 particles of gold are contained in a cubic inch of that metal: 500,000 particles of iron might also be capable of occupying the same space, and 100,000 particles of wood. In the iron and wood there must, therefore, be many more pores, or interstices, than in the gold; and of course the gold will be the heaviest, or most dense. This increased density and weight do not therefore arise from the individual particles of gold being heavier than those of wood, but from a greater number of them being forced into the same space; for the original particles of matter are presumed to be all of the same weight; and thus gold, which is one of the heaviest solids, will, when dissolved, remain suspended in ether, which is the lightest of all visible fluids. It is impossible to obtain the absolute weight of bodies

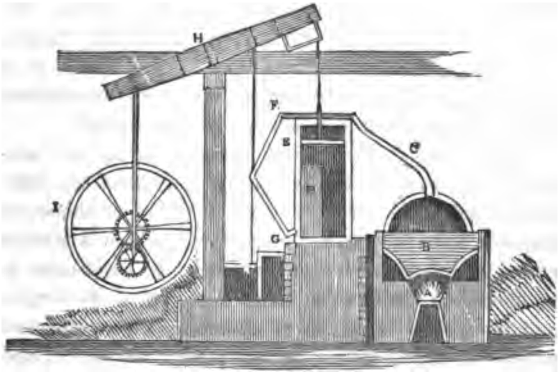
which vary in density, by weighing them in the open air, for the air will buoy up that which has the least density more than that which has the greatest. And thus, although a piece of cork and a piece of lead may exactly balance each other at the ends of a scale-beam, yet that balance will be destroyed as soon as they are placed in an exhausted receiver; for then the cork, by losing the buoyant assistance of the air, will preponderate; thereby proving that it contains more matter than the lead, though not in the same compass. This principle is sometimes further elucidated by the experiment of letting a guinea and a feather fall together in a glass receiver: when this is full of air, the guinea falls while the feather is floating about; but when the air is withdrawn from the receiver, they both reach the bottom at the same instant.

Since the earth is of a globular form, and the power of attraction is in proportion to the quantity of matter, so, of course, the inhabitants, and all things upon the earth's surface, will be attracted, or drawn downwards, in a direction tending to its centre; for since the longest line which can be drawn through a circle, or globe, is a diameter which must pass through its centre, so this will likewise pass through the greatest quantity of matter contained in any one direction in it, and consequently all bodies will fall in a direction pointing to the centre of the earth. Hence the use of plumb-lines for obtaining perpendiculars to the horizon, for setting the sides of buildings upright, &c.

Besides the above-described five properties of matter, it possesses yet another property, of great importance—namely, its power of arrangement, commonly

called *polarity.* The attraction of cohesion sufficiently accounts for the formation of masses, or substances, by drawing the original particles of matter together, and then holding them in contact; but it is found that they are not only drawn and held together, but that the same matter always takes the same arrangement, or formation. Thus a piece of iron, tin, or any other metal, or mineral, will, when broken, always exhibit the same arrangement and disposition of parts, or *grain*, as it is generally called. And so strictly are the laws of combination found to prevail in the union of elements, and formation of substances, that a novel and important character is given to modern chemical researches, approaching almost to mathematical precision; it being ascertained not only that the same materials will, in most cases, assume the same form, but that the ingredients which enter into the composition of substances do so in certain definite proportions, which cannot be changed without also changing the character of the substance they form.

THE MECHANICAL POWERS.

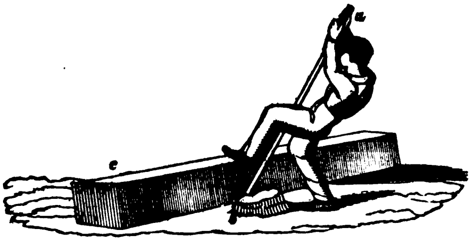


The Mechanical Powers are certain simple arrangements of machinery, by means of which weights may be raised, or resistance overcome, with the exertion of less power, or strength, than is necessary without them. In a mechanic power, the weight, or resistance, to be acted upon, and the power, or strength, which acts upon it, should both move at the same time; and any thing constitutes a mechanic power, in which the motion of the power produces a simultaneous motion in the resistance, provided less power is necessary than is due to the weight, or strength, of such resistance. From this general definition, it might appear that

every machine capable of generating force would be a mechanic power; but simplicity is likewise essential, and hence the mechanical powers may be said to be the elements of machinery; and they are, in fact, so elementary as to admit of no simplification or alteration. They are but six in number; and the names by which they are distinguished are, the LEVER, the WHEEL AND AXLE, the PULLEY, the INCLINED PLANE, the WEDGE, and the SCREW. Out of the whole, or a part, of these, it will be found that every mechanical engine, or piece of machinery, is constructed.

THE LEVER. This is the simplest of all the mechanical powers, and is generally considered the first. It is an inflexible bar, or rod, of any kind or shape, so disposed as to turn on a pivot, or prop, which is always called its *fulcrum*. It has the weight, or resistance, to be overcome, attached to some one part of its length, and the power which is to overcome that resistance applied to another; and as the power, resistance, and fulcrum admit of various positions with regard to each other, so the lever is divided into three modifications, distinguished as the first, second, and third kinds of lever — that portion of it which is contained between the fulcrum and the power being called the acting part, or arm, of the lever; and that part which is between the fulcrum and the resistance, its resisting part, or arm.

A beam, or rod, of any kind, resting at one part on a prop, or axis, which becomes its centre of motion, is a lever; and it has been so called, probably, because such a contrivance was first employed for lifting weights. This figure represents a lever used to move



a block of stone: *a* is the end to which the power, or force, is applied; *b* is the prop, or fulcrum; and *c* is the weight, or resistance: this is a simple crowbar, or hand-spike. According to a fundamental principle of dynamics, the power may be as much less intense than the resistance as it is farther from the fulcrum, or moving through a greater space. A man at *a*, therefore, — twice as far from the prop as the centre of gravity of the weight, *b*, — will be able to lift a weight twice as heavy as himself; but he will lift it only one inch for every two that he descends; for it is also a principle of this science that what is gained in power is lost in time.

There is no limit to the difference of intensity in forces which may be placed in opposition to each other by the lever, except the length and strength of the material of which the levers must be formed. Every one has heard of the boast of Archimedes, "Give me a lever long enough, and a prop strong enough, and with my own weight I will move the world!" But he must have moved with the velocity of a cannon-ball for millions of years, to alter the position of the earth

half an inch. In mathematical truth, this feat of Archimedes is performed by every man who leaps from the ground, for he kicks the world away from him when he rises, and attracts it again when he falls back.

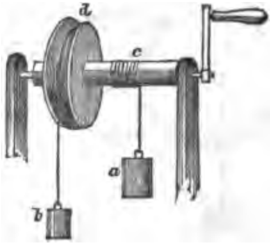
The common claw-hammer for drawing nails is a striking example of the power of a lever of this description. A boy who cannot exert a direct force of fifty pounds may, by means of this kind of hammer, extract a nail to which half a ton may be suspended, because his hand moves eight inches, perhaps, to make the nail rise one quarter of an inch. The claw-hammer also proves that it is of no consequence whether the lever be straight or crooked, provided it produces the required difference of velocity between power and resistance. The part of the hammer resting on the plank is the fulcrum. Pincers, or forceps, are double levers, and so are common scissors. The steelyard is a lever with unequal arms.

The second kind of lever possesses the same degree of power with the first, and operates with the same results. The third kind cannot be called a mechanical *power*, for, since its resisting arm is longer than the acting arm, it must *lose* power, though it gains time. The most familiar examples of the occurrence of this kind of lever, are in the use of common fire-tongs, and in rearing a tall ladder against a wall. But the circumstance that principally gives importance to it, is, that the limbs of men and all animals are formed of it; for the bones are levers, the joints are the fulcra, while the muscles which give motion to the limbs, or

produce the power, are inserted and act close to the joints, causing action at the extremities.

To calculate the effect of a lever in practice, we must always take into account the weight of the lever itself, and its bending. But in speaking of the theory of the lever, we usually leave these out of the question, considering it as a rod without weight or flexibility.

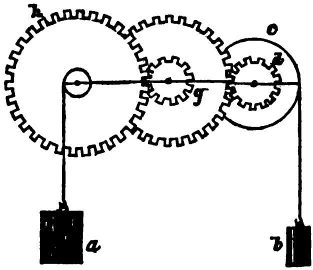
THE WHEEL AND AXLE. This power consists of two parallel wheels, pulleys, cylinders, or circles, having one axis in common. The letter *d* here marks the



wheel, and *c* an axle affixed to it. We see that, in turning together, the wheel would take up, or throw off, as much more rope than the axle as the circumference of the wheel is greater than that of the axle. If the proportions were as four to one, one pound, at *b*, hanging from the circumference of the wheel, would balance four pounds at *a*, hanging from the opposite side of the axle. A common crane for raising weights consists of an axle, to wind up, or receive, the rope which carries the weight, and of a large wheel, at the circumference of which the power is applied. The power may be animal effort on the outside of the wheel, or

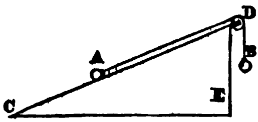
the weight of a man, or beast, walking on the inside, and moving it as a squirrel moves the cylinder of his cage.

By means of a wheel which is very large in proportion to its axle, force of very different intensities may be balanced, but the machine becomes of inconvenient proportions. It is found preferable, therefore, when a great difference of velocity is required, to use a combination of wheels, of moderate size. In the following figure, three wheels are seen thus connected. Teeth



in the axle, *d*, of the first wheel, *c*, acting on six times the number of teeth in the circumference of the second wheel, *g*, turn it only once for every six times that *c* revolves. In the same manner the second wheel, by turning six times, turns the third wheel, *h*, once; the first wheel therefore turns thirty-six times for one turn of the last; and as the diameter of the wheel *c*, to which the power is applied, is three times greater than that of the axle, which has the resistance, three times 36, or 108, is the difference of velocity:—therefore 1 pound at *b* will balance 108 pounds at *a*.

On the principle of combined wheels, cranes are made, by which one man can lift many tons. It is even possible to make an engine, by means of which a little windmill, of a few inches in diameter, could tear up the strongest oak by the roots; but of course this would require a long time for its work. The most familiar instances of wheel-work are in our clocks and watches. One turn of the axle on which the watch-key is fixed, is rendered equivalent, by the train of wheels, to about 400 turns, or beats, of the balance-wheel; and thus the exertion, during a few seconds, of the hand which winds it up, gives motion for 24 or 30 hours. By increasing the number of wheels, time-pieces are made which go for a year; and if the material would last, they might easily be made to go for a thousand years.



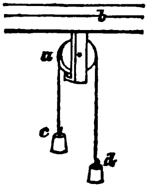
The Inclined Plane is described by the above cut. A force pushing a weight from C to D, only raises it through the perpendicular height, E D, by acting along the whole length of the plane, C D; and if the plane be twice as long as it is high, one pound at B, acting over the pulley, D, would balance two pounds at A, or any where on the plane; and so of all other quantities and proportions. A horse drawing on a road where there is a rise of one foot in twenty, is really *lifting* one twentieth of his load, as well as overcoming the friction and other resistance of the carriage. Hence

the importance of making roads as level as possible; and hence the error, which has often been committed, of carrying roads directly over hills, for the sake of straightness, when, by going round the bases of the hills, the distance would scarcely have been increased, and all rising and falling would have been avoided. Hence, also, a road up a very steep hill must be made to wind, or go zigzag, all the way; for, to reach a given height, the ease of the pull to the horses is greater, exactly as the road is made longer. An intelligent driver, in ascending a steep hill by a broad road, winds from side to side all the way, to save his horses what little he can.

Hogsheads of merchandise, which twenty men could not lift by applying their strength directly, are often seen moved out of, or into, wagons by one or two men who have the assistance of inclined planes. On some canals and railroads, the loaded boats and cars are drawn up by machinery on inclined planes. It is supposed that the ancient Egyptians must have used this mechanical power to assist in elevating and placing those immense masses of stone with which their pyramids and other gigantic piles of architecture were constructed.

In our speculations upon the power of the inclined plane, we suppose the plane to be perfectly smooth, and that bodies move upon it without friction or impediment; but this can never be the case in practice, even in the most perfect machines; consequently, some allowance must be made from the calculated effect, and when carriages move upon rough or sandy roads, this allowance must be considerable.

THE PULLEY. A pulley is a grooved wheel, around which a rope is passed, and is either fixed or movable.



The preceding cut represents a fixed pulley, which never changes its position: *a* is the wheel; *b* a beam, or roof, from which the wheel is suspended; *c* is the power hanging at one end of the rope; and *d* is the weight at the other end. In such a construction, it is evident that the weight — for instance, ten pounds — is equally supported by each end of the rope, and that a man holding up one end, only bears half of it, or five pounds; but to raise the weight one foot, he must draw up two feet of rope; therefore, with the pulley, he lifts five pounds two feet, when he would be obliged to lift ten pounds one foot without the pulley.

This kind of pulley, however, possesses no mechanical advantage. To raise a pound weight from the ground at one end of the cord, the power of one pound must be exerted at the other. Its object, then, is not to save power, but to give convenience in pulling. For instance, by pulling downwards, a weight may be raised upwards; or, by pulling in one direction, a load may be made to proceed in another. Thus, in drawing a bucket out of a well, it is much easier to pull downwards, by means of a rope passing through a pulley

over the head, than upwards, by drawing directly at the bucket.

Many wheels may be combined together, and in many ways, to form compound pulleys. Wherever there is but one rope running through the whole, as

shown here, the relation of power and resistance is known by the number of folds, or turns, of the rope which supports the weight. Here are six turns, and a power of one hundred pounds would balance a resistance of six hundred. The chief use of this pulley is on board ships, where it is called a *block*. It aids so powerfully in hoisting the masts and sails, &c., that, by means of it, a small number of sailors are rendered equal to the duties of a large ship.

There is no assignable limit to the power which may be exerted by means of pulleys. A machine may be constructed to raise with ease any weight which the strength of the materials will bear, provided the com-

bination be not so complex as to exhaust the power by the friction produced.

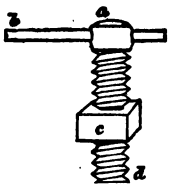
THE WEDGE. This power acts on the principle of an inclined-plane force moving forward between resistances, to overcome or separate them, instead of being stationary, while the resistance is moved along its surface. The same rule, as to mechanical advantage, has

been applied to both cases, the force acting on the wedge being considered as moving through a space equal to its length, C D, and the resistance as yielding through a space equal to its breadth, A B. But this rule is far from explaining the extraordinary power of the wedge. It appears that, during the tremor produced by the blow of the driving-hammer, the wedge insinuates itself, and advances much more quickly than the above rule anticipates. The wedge is used for many purposes, as for splitting blocks of stone and wood; for squeezing strongly, as in the oil-press; for lifting great weights, as when a ship of war, in dock, is raised by driving wedges under her keel. An engineer in London, who had built a very lofty and heavy chimney for his steam engines and furnaces, found, after a time,

that it was beginning to lean on one side. By driving wedges under that side, he succeeded in restoring it to a complete perpendicular.

The wedge is the least used of the simple mechanical powers, but the principle upon which it acts is in extensive application. Needles, awls, bodkins, and driving nails, are the most common examples. Knives, swords, razors, the axe, chisel, and other cutting instruments, also act on the principle of the wedge; so likewise does the saw, the teeth of which are small wedges, and act by being drawn along while pressed against the object operated upon. When the edge of a scythe, or razor, is examined with a microscope, it is seen to be a series of small, sharp angularities, of the nature of the teeth of a saw.

THE SCREW may be considered as a winding wedge; for it has the same relation to a straight wedge that a road, winding up a hill or town, has to a straight road of the same length and acclivity. A screw may be



described as a spindle, *a d*, with a thread wound spirally round it, turning or working in a nut, *c*, which has a corresponding spiral furrow fitted to receive the thread. Every turn of the screw carries it forward in a fixed nut, or draws a movable nut along upon it, by exactly

the distance between two turns of its thread; this distance, therefore, is the space described by the resistance, while the force moves in the circumference of the circle described by the handle of the screw, as at *b*, in the figure. The disparity between these lengths, or spaces, is often as a hundred, or more, to one; hence the prodigious effects which a screw enables a small force to produce. Screws are much used in presses of all kinds; as in those for squeezing oil and juice from vegetable bodies, as linseed, rape-seed, almonds, apples, grapes, sugar-cane, &c. They are used in the cotton-press, which reduces a great spongy bale, of which a few, comparatively, would fill a ship, to a dense package heavy enough to sink in water; and in the common printing-press, which forces the paper strongly against the types. The screw is the great agent in the coining machinery of mints.

As a screw can easily be made with a hundred turns of its thread in the space of an inch, and at perfectly equal distances from each other, it enables the mathematical instrument maker to mark divisions on his work with a minuteness and accuracy quite extraordinary. When a screw is at liberty to move equally in all directions, it is simply called a *screw;* but when it is confined at its ends, so that it can merely revolve, without advancing or withdrawing, it is called an *endless screw*,—and in this case it generally acts into the teeth of a wheel, either to move or be moved by that wheel; but its power is alike in both cases. The screw, though a mechanical power, can hardly be called a simple instrument, because, from its great friction, it always requires the assistance of a lever to turn it; and when

so turned, its power is estimated by taking its circumference, and dividing this by the distance between any two of its threads.

Yet, after all, there seems to be no reason, except long-established usage, why the appellation of Mechanical Powers should be restricted to the six contrivances above explained; for many others equally deserve it; and, in fact, the mightiest of all mechanical devices, the steam engine, does not derive its power from solid substances at all.

HYDROSTATICS.

THIS science has for its object the examination of the mechanical laws which regulate the motions, pressure, gravitation, and equilibrium, of inelastic fluids, as well as their effects upon bodies which float upon or are immersed in them. The construction of pumps and machines for raising and conveying water, and of machinery to be moved by it, is made a separate branch of the same inquiry, under the name of HYDRAULICS, which will be the subject of the next chapter.

The incompressibility of water had long been suspected, but was first fairly put to the test in the Academy del Cimento at Florence, in 1650. A quantity of pure water was introduced into a hollow sphere of gold, as being the most dense and compact metal, and a screw, working in a water-tight joint, was then forced into the globe among the water, by which it was compressed with great force; and it was found that the water refused to admit of this compression, but actually oozed through the pores of the metal, and appeared like dew on the outside of the globe. This process is called the *Florentine experiment.*

Mr. Canton afterwards repeated this experiment in a very accurate manner, and with some variation of form. He enclosed a quantity of mercury in a glass

tube similar to those used for thermometers, but of greater dimensions, and he observed to what point the mercury rose when the whole was heated to 50 degrees of Fahrenheit: after this, the mercury was made to expand, by increased heat, until the whole tube was filled, and in this state its end was hermetically sealed. The mercury, being thus relieved from the pressure of the atmosphere, did not fall down to its original situation, but stood nearly a third of an inch higher than before, by which mercury was proved to be an expansible, and consequently a compressible, fluid. The tube was now emptied; and water which had been long boiled, to clear it from any air which it might contain, was substituted in the place of mercury, and treated in the same manner. The water was found to stand nearly half an inch higher, when relieved from atmospheric pressure, than it did before; from which it was inferred that water is slightly compressible, though to so small a degree as to be of no consequence in practice.

This experiment, however, was on a very small scale, and nothing further was done towards ascertaining the degree of condensation that water would admit of, till Mr. Perkins, an American, tried some very ingenious and decisive experiments upon it. He was first led to the subject by the contemplation of a simple, but hitherto unexplained fact; namely, that, when a bottle, completely filled with water, well corked and secured, was sunk into the deep sea by a heavy weight, it always returned again to the surface, either with the cork pushed into the inside, or protruded in a greater or less degree; but the water in the bottle was, in all cases,

turned from fresh to salt. Mr. Perkins, therefore, tried several experiments of this sort with cylinders of brass and iron, constructed for the purpose. The result of these trials established the fact of the compressibility of water in the most satisfactory manner. 30,000 pounds pressure to the inch will lessen its bulk one twelfth.

Fluids have weight, and gravitate towards the earth, according to their density, in the same way that solids do; but, from the want of cohesion among their particles, they are incapable of assuming any particular form without assistance, and, consequently, they always take the shape of the vessel which contains them. They also exert a certain force against the sides of that vessel, from their tendency to fall, which constitutes their lateral pressure; for fluids not only press downwards with their whole might, in obedience to gravitation, but they press sideways, or laterally, in all directions at the same time, and from the same cause; and consequently, no fluid can remain in a state of quiet equilibrium unless every part of its surface is equidistant from the centre of the earth, or in what is generally called a *level plane*, though that apparent plane is, in fact, not a plane, but partakes of the convexity of the earth. And it is for the purpose of establishing such an equilibrium that fluids always run from a higher to a lower situation.

For the purpose of explaining the manner in which the surfaces of fluids become level, it may be very fairly supposed that the particles of which they are composed are placed one upon another, so as to form what may be termed pillars or columns of particles; and supposing all the particles to be of the same size

and weight, the columns on one side of the vessel will be an exact balance to those on the other side. The cause of bodies floating upon fluids, or sinking in them, may be explained the same way; for, whenever a solid is immersed in a fluid, it displaces a quantity of water, and consequently renders the columns of particles underneath it shorter, and, therefore, lighter, than those which surround it. But the weight of the floating body becomes a counterpoise to the greater length of the surrounding columns, and must in every case be precisely equal to the quantity of water which it displaces. Consequently, all things which are lighter than their own bulk of water will swim, and all that are heavier must sink. A ship, therefore, of 500 tons' burden must displace 500 tons of water from the bed, or hollow, which it makes from the keel up to the water line; and in this way the actual tonnage of a ship is estimated, although her nominal burden is fixed by another species of measurement.

The truth of this position is very satisfactorily proved by putting the model of a ship into a scale, and exactly balancing it with water in the other scale. The ship is then removed, and placed in a small cistern quite filled with water, when a quantity of it will flow over, and, on taking the ship out, it will be found that the vacuity will be exactly filled by the water in the scale, being the *weight* of the floating body.

Notwithstanding the above experiments seem to prove that the pressures of fluids are in consequence of a mechanical equilibrium, dependent upon the gravitation of equal quantities of matter acting against each other, yet, on more mature examination, it is

found that such pressures are regulated by perpendicular height, and the area of the surface acted upon, without any regard to quantity, or absolute gravity. For, although a pound of water can, in itself, produce no greater effect than is due to a pound, yet, from the properties of fluids, it may be so disposed as to produce the effect of many hundred pounds. This has obtained the name of the *hydrostatic paradox.* The bottom of a vessel bears a pressure proportional to the height of the liquid; so likewise do those parts of the sides which are contiguous to the bottom, because the pressure of fluids is equal every way. Thus the sides of a vessel must every where sustain a pressure proportional to their distance from the upper surface of the liquid; whence it follows that, in a vessel full of a liquid, the sides bear the greatest stress in those parts next the bottom, and the stress upon the sides decreases with the increase of the distance from the bottom, and in the same proportion; so that, in vessels of considerable height, the lower parts ought to be much stronger than the upper. This has been illustrated by a striking experiment. A strong, though small, tube of tin, twenty feet high, was inserted in the bung-hole of a hogshead: water was poured in till it rose within a foot of the top of the tube; the hogshead then burst, and the water was scattered about with incredible force.

The running, or spouting of fluids, from the sides of vessels, arises, likewise, from lateral pressure, and is, consequently, influenced by the height of the column, without regard to the quantity it contains: consequently, if any given quantity of water issues in a certain time

from a hole in a cask, or reservoir, double that quantity will issue from another hole, of precisely the same dimensions, if it be situated four times as deep as the first, below the surface of the fluid. A similar hole, nine times as deep, will deliver three times as much fluid in the same time. The discharge is, therefore, as the square root of the depth beneath the surface; which law is of great importance in the practical construction and arrangement of water-works, and, if not attended to, may occasion a great waste of power.

From the principles already advanced, it follows that a stream will always rise as high as its fountain-head: that is, if a tube, twenty miles long, and rising and descending among the inequalities of the land, were nearly filled with water, and could have its ends brought together for comparison, it would exhibit two liquid surfaces, having precisely the same level, and, on either end being raised, the fluid would sink in it, to rise in the other. If there were two lakes, on adjoining hills, of different heights, a pipe of communication descending across the valley, and connecting them, would soon bring them to the same level; or, if one were much lower than the other, it would empty the latter into the former. The ancient method of supplying cities with water was by means of aqueducts, or bridges, built over the valleys, and supporting either pipes, or a conduit, or channel. These stupendous and costly erections, the remains of which still adorn the ruins of ancient cities, are supposed to have owed their origin to an ignorance of the above principle of hydrostatics; but it is quite as probable that the ancients were compelled to erect these structures by the practical difficulty

of uniting a long range of pipes in such a manner as to remain perfectly water-tight against the pressure of a heavy column of water. This is not easy even in the present improved state of the mechanic arts, and with all the advantage of cast-iron and the most durable materials, instead of stone and earthenware, which appear to have been chiefly used for pipes in the construction of the older water-works. Even at the present day, it is found more convenient to conduct water to cities, from long distances, by open aqueducts than by pipes, as has been done at New York. Here the purest water is conveyed from the River Croton, which is forty-one miles from the city, to a reservoir which will hold 150,000,000 gallons. From this reservoir, it is carried by pipes to all parts of the city, in sufficient quantities to supply every demand for it, for domestic uses, for watering streets, and extinguishing fires.

What has been said upon water-works equally applies to fountains; for a jet can be produced only by the effort of water to rise to its level, or by its being under the influence of condensed air, or some other force. Thus, if an elevated cistern, or reservoir, be kept supplied with water, and a tube descends from its lower part, ending in a small orifice pointing upwards, the water will spout from it, and form a jet nearly equal in height to that of the water from which it is supplied; but, for want of that support which the fluid derives from the sides of a tube, or close vessel, and from its being in constant and rapid motion through the resisting air, it will never gain the full height of the column of supply.

Since the weight which a body loses, when immersed

in a fluid, is always the weight of as much of that fluid as is equal in bulk to itself, it follows that the weight lost by the body cannot at all depend either on the depth of the fluid itself, or the depth to which the body is immersed. An anchor loses no more of its weight when it is at the bottom, than when it is just below the surface; for in both cases it loses the weight of as much water as is equal in bulk to itself. It is not easier to swim in deep than in shallow water; for whatever is the depth, a man loses the weight of as much water as is equal in bulk to his own body; for which reason, shallow water will buoy him up with as great force as deep water. Indeed, it is easier to swim in the sea than in a river, because salt water is specifically heavier than fresh. In the Dead Sea, the water of which is more deeply saturated with salt than any other body of water in the world, this principle is strikingly illustrated. In the Travels of Mr. Stephens is the following account of his attempting to swim in this lake: "I know, in reference to my own specific gravity, that, in the Atlantic or Mediterranean, I cannot float without some little movement of the hands, and even then, my body is almost totally submerged; but here, when I threw myself upon my back, my body was half out of water. It was an exertion even for my lank Arabs to keep themselves under. When I struck out, in swimming, it was exceedingly awkward; for my legs were constantly rising to the surface, and even above the water. I could have lain there and read, with perfect ease. In fact, I could have slept."

There are few, if any, animals that are specifically heavier than common water. The substances, indeed,

of both animals and vegetables, are specifically heavier; the floating of either is, therefore, to be attributed to the cells, or receptacles, interspersed within them, which are filled with air, oil, and substances lighter; so that, taken together, they form a mass specifically lighter than common water. Thus the bulk of the body is increased by distending the chest in inspiration; this has been tried by an experiment on a fat man, of an ordinary size, by finding what weight he could support, so as to have the top of the head just above water. When his lungs were full of air, he was found to rise with fourteen pounds of lead; but on breathing out the air, he could sustain only eleven pounds.

To show the practical purposes the principle here illustrated may serve, we will relate the story of Hiero's crown. Hiero, king of Syracuse, had delivered a certain weight of gold to a workman, to be made into a crown; the latter brought back a crown of the proper weight, which was afterwards suspected to be alloyed with silver. The king applied to the celebrated mathematician, Archimedes, to know how he might detect the cheat, the difficulty being to measure the bulk of the crown, without melting it into a regular figure: silver being, weight for weight, of greater bulk than gold, any alloy of the former, in place of an equal weight of the latter, would mechanically increase the bulk of the crown. Archimedes was at first embarrassed with this problem; but one day, on going into a bath, which happened to be quite filled with water, he was struck with the simple fact that a quantity of water, of the same bulk as his body, must flow over before he

could immerse himself. It immediately occurred to him that, by immersing a weight of pure gold, equal to that which the crown ought to have contained, in a vessel full of water, and observing how much water was left when the gold was taken out, and by afterwards doing the same thing with the crown itself, he could ascertain whether the latter exceeded the former in bulk. The moment he was struck with this thought, his exultation was so great that he leaped out of the bath, and, without stopping to put on his clothes, ran home, crying out, "*Eureka!*" "I have found it!" an expression which has become proverbial.

HYDRAULICS.

Water, as we have already remarked, may be made a useful agent of power, merely by allowing it to act with the force of its own gravity, as in turning a mill; and in this manner it is extensively employed in all civilized countries possessing streams which are suf-

ficiently rapid in their descent. But water may be rendered otherwise useful as an agent of force in the arts. Although subtile in substance, and eluding the grasp of those who attempt to handle it, water can, without alteration of temperature, be made to act, as a mechanical power, as conveniently and usefully as if it were a solid substance, like iron, stone, or wood. The lever, the screw, the inclined plane, or any of the ordinary mechanical powers, are not more remarkable as instruments of force than water, a single gallon of which may be made to perform what cannot be accomplished, except at enormous cost and labor, by the strongest metal.

To render water serviceable as an instrument of force, it must be confined, and an attempt then be made to compress it into less than its natural bulk. In making this attempt, the impressed force is freely communicated through the mass, and, in the endeavor to avoid compression, the liquid will repel whatever movable object is presented to it. The force with which water may be squirted from a boy's syringe gives but a feeble idea of the power of liquids, when subjected, in a state of confinement, to the impression of external force.

We have already spoken of the tendency of water to seek every where a common level, on the principle of which aqueducts are constructed. Springs in the ground are natural hydraulic operations, and are accounted for on principles connected with the laws of fluids. One class of springs is caused by capillary attraction, or natural attractive forces, by which liquids rise in small tubes, porous substances, or between flat

bodies, closely laid together. This species of power is a remarkable variety of the mutual attraction of matter, and is as unaccountable as the attraction of gravitation, or the attraction exercised by the load-stone. Springs from capillary attraction are believed to be less common, and of less importance, than springs which originate from the obvious cause of water finding its level. The water which falls in the form of rain sinks into the ground in high situations, and finds an outlet at a lower level, though perhaps at a considerable distance.

The friction, or resistance, which fluids suffer when passing through pipes, is much greater than might be expected. It depends chiefly upon the particles being constantly driven from their direct course by the irregularities in the surface of the pipe. An inch tube, of 200 feet in length, placed horizontally, is found to discharge only a fourth part of the water which escapes by a simple aperture. Air, likewise, in passing through tubes, is retarded, as was discovered by a person who constructed a great bellows at a waterfall, to blow a furnace two miles off. This resistance is so great, that when it was first proposed to lay gas-pipes in England, some engineers were of opinion that the gas could not be forced through them. All liquids flow faster through an orifice, or pipe, the higher their temperature is kept, as this diminishes that cohesion of parts which exists, to a certain degree, in all of them, and affects so much their internal movements. The flux of water through orifices, under uniform circumstances, is so regular, that, before the invention of clocks and watches, it was employed as a means of measuring time. These

water-clocks were called *clepsydræ*, and were often used by ancient orators, to show them when the time allotted to them for speaking had expired. The common hour-glass of running sand is another modification of the same principle.

The progress of water, in an open conduit, such as the channel of a river, or an aqueduct, is influenced by friction in the same manner. But for this, and the effect of bending, a river, like the Rhone, drawing its waters from an elevation of a thousand feet above the level of the ocean, would pour them out with the velocity of water issuing from the bottom of a reservoir a thousand feet deep; that is to say, at the rate of 170 miles an hour. The ordinary flow of rivers is about 3 miles an hour, and their channels slope three or four inches a mile. Three feet fall, a mile, makes a mountain torrent. The friction of water, moving in water, is such, that a small stream directed through a pool, and rapid enough to rise over the opposite bank, will soon empty the pool. Large fenny tracts have been drained in this manner. The friction between air and water is also singularly strong, as is proved, on a great scale, by the magnitude of the ocean waves which are caused by it. A little oil, thrown upon the surface of the water, spreads as a thin film all over it, and defends it from further contact and friction of air. If this is done at the windward side of a pond, where the waves begin, the whole surface will soon become as smooth as glass; and even out at sea, where the commencement of the waves cannot be reached, oil thrown upon them smooths their surface, and prevents their curling over and breaking.

A stone thrown into a smooth pond causes a succession of circular waves to spread from the spot where it falls. They become of less elevation as they expand, and each new one is less raised than the preceding, so that gradually the liquid mirror is again as perfect as before. Several stones falling at the same time in different places cause crossing circles, which, however, do not check the progress of each other — a phenomenon seen in beautiful miniature at each leap of the little insects which cover the surfaces of ponds in the calm days of summer. Such waves are caused in this manner: When the stone falls into the water, because the liquid is incompressible, a part of it is displaced laterally, and becomes an elevation, or circular wave, around the stone; this wave then falls downward and outward, in obedience to the laws of fluidity, and the circle is seen to spread. In the meantime, where the stone descended, a hollow is left for a moment in the water, but, owing to the surrounding pressure, it is soon filled up by a sudden rush from below. The rising water does not stop, however, at the exact level of that around, but, like a pendulum, sweeping past the centre of its arc, it rises as far above the level as the depression was deep. This central elevation now acts as the stone did originally, and causes a second wave, which pursues the first, and, when the centre subsides, like the pendulum still, it sinks again as much below the level as it had mounted above; hence it must again rise, again to fall, and this for many times, sending forth a new wave at each alternation. Owing to the friction among the particles of

water, each new wave is less raised than the preceding, and at last the appearance dies away.

The common cause of waves is the friction of the wind upon the surface of the water. Little ridges, or elevations, first appear, which, by the continuance of the force, gradually increase till they become rolling billows. The heaving of the Bay of Biscay, or, still more remarkably, that of the open ocean between the southern capes of America and Africa, exhibits one extreme, and the stillness of the tropical seas, which are sheltered by encircling land, exhibits the other. In sailing round the Cape of Good Hope, waves are met with so vast, that a few ridges and depressions occupy the extent of a mile. But these are not so dangerous to a ship as a shorter sea, with more perpendicular waves. The slope in the former is so gentle, that the rising and falling are scarcely felt, while the latter, causing an abrupt and violent pitching of the vessel, are often destructive. The unfortunate steam-ship President doubtless perished from this cause. She encountered a tremendous gale on the day after leaving New York, and, during the height of its fury, she must have been at a point where the Gulf Stream approaches the shoal called George's Bank, and causes an almost perpendicular surge of the most dangerous character. The ship was last seen struggling ahead directly against the sea, and pitching violently. Her enormous length must have greatly added to the danger, and probably caused her soon to rack to pieces.

The velocity of waves is in proportion to their magnitude. The largest waves move from thirty to forty

miles an hour. It is a vulgar belief that the water itself advances with the speed of the wave, whereas it is only the *form* that advances, while the substance, with the exception of a little spray above it, remains rising and falling in the same place, with the regularity of a pendulum. A wave of water, in this respect, is exactly imitated by the wave running along a stretched rope when one end is shaken, or by the mimic waves of our theatres, which are generally undulations of cloth shaken up and down. But when a wave reaches a shoal, or beach, the water becomes really progressive, because then, as it cannot sink directly downwards, it falls over and forwards, seeking its level.

So terrific is the spectacle of a storm at sea, that it is generally viewed through a medium which biases the judgment; and, lofty as waves really are, imagination pictures them loftier still. Now, no wave rises more than ten feet above the ordinary sea level, which, with the ten feet that it afterwards descends below it, give twenty feet, from the hollow, or *trough*, of the sea, as the sailors call it, to the adjoining summit. The spray of the sea, driven along by the violence of the wind, is, of course, much higher than the crest of the wave, and a wave coming against an obstacle may dash to a great elevation above it. At the Eddystone lighthouse, in the English Channel, in heavy storms, the waves dash over the top of the lantern.

On a superficial view of the doctrine of resistance, in the case of bodies moving through a fluid, many persons would conclude that, if a body moving through the water at a given rate, meets a given resistance, it should encounter double that resistance when moving

at double the rate; but this is a fallacy; the resistance is four times greater with a double rate. The reason is very clear. A boat which moves one mile an hour displaces a certain quantity of water, and with a certain velocity; if it moves twice as fast, it of course displaces twice as many particles in the same time, and requires to be moved with twice the force on that account. But it also displaces every particle with a double velocity, and requires another doubling of the power on this account; the power therefore, being doubled on two accounts, becomes a power of four. In the same manner, with a triple speed, three times as many particles are moved, and each particle with a triple velocity; therefore, a force of nine must be applied to overcome the resistance. For a speed of four, sixteen is wanted, and so on. Thus, even if the resistance against the bow of the vessel only were considered, one hundred horses would drag a canal-boat only ten times faster than one horse. But there is another important element in the calculation—namely, the lessening of the usual water-pressure on the stern of the vessel as she moves forward, on account of which, the force required to produce an increased velocity is still greater than what is shown by the above calculation.

There is not a more important truth in physics than this; it explains so many phenomena of nature, and becomes a guide in so many matters of art. It explains in what manner so great an expenditure of fuel is required to obtain high velocities in steamboats. It shows the folly of crowding sail upon a ship with a strong breeze, the trifling advantage in point of speed

by no means compensating for the wear of the sails and the risk of accidents. No seamen practise this so much as the Americans, who are ready to incur any degree of expense, and run any risk, in the hope of gaining a little time. We remember an instance where a Boston merchant said to one of his shipmasters about to sail, "Wear out what you please, but make a quick passage."—This ship returned from Europe, having worn out an entire new set of sails in one voyage. The above law explains, also, why a ship glides through the water one or two miles an hour with very little wind, although, with a powerful breeze, she would sail only eight or ten. Less than the 100th part of that force of wind which drives her ten miles an hour will drive her one mile; and less than the 400th part will drive her half a mile. Thus, also, during a calm, a few men pulling in a boat can tow a large ship.

If a ship be anchored in a stream where the current is four miles an hour, the strain on her cable is not one fourth part so great as if the current were eight miles. The rapid increase of resistance, in proportion to the increase of velocity, shows that we soon reach the maximum of speed in ships. Fifteen miles an hour is the utmost that a ship can sail. No fish swims faster than twenty miles an hour. The flight of birds, also, has a limited celerity; but as the thin air opposes much less resistance than water, flying is, of course, more rapid than sailing or swimming. The crow, when flying homeward against the storm, cannot face the wind in the open sky, but skims along the surface of the earth in deep valleys, and wherever the swiftness of the wind is retarded by terrestrial obstacles.

The great albatross can stem upon the wing the current of a gale, keeping company with a driving ship when the wind is passing at the rate of a hundred miles an hour; but perhaps this is the limit to which winged speed can reach.

If a flat surface experience a certain resistance, a projecting surface, like that of a ball or wedge, is resisted in a less degree. The explanation is, that a flat surface throws the particles of fluid almost directly outwards from its centre to its circumference; but the convex or wedge-like surface, while displacing them just as far, does it more slowly, and therefore with less expenditure of force in proportion as its point is in advance of its shoulder, or broadest part. The shape of the hinder part of a solid moving through a fluid is of importance, for corresponding reasons. Fishes are wedge-like both before and behind: so are birds, and they stretch out their necks while flying, so as to become like sharp points dividing the air. In the form of the under part of boats and ships, men have imitated the shape of fishes. There are boats used by the Chinese called *snake-boats*, which are only a foot or two in width, but a hundred feet long, and when rowed, as they often are, by a hundred oars, their swiftness is excessive. Oars for boats are made flat, and often a little concave, that the mutual action between them and water may be as great as possible. The webbed feet of water-fowl are oars; in advancing, they collapse, like a shutting umbrella, but open outwards in the thrust backward, so as to offer a broad concave surface to the water. The expanded wings of birds are, in like manner. a little concave towards the air

which they strike. The sails of ships, when they are receiving a fair wind, are left slack, so as to swell and become hollow.

We conclude this topic by the following striking example of the power of water, given by Mr. Olmstead: "A waterfall like that of Niagara, where an immense body of water rolls first in rapids down a long inclined plane, and then descends perpendicularly from a great height, affords one of the greatest exhibitions of mechanical power ever seen. The Falls of Niagara contain power enough to turn all the mills and machines in the world. They waste a greater amount of power every minute than was expended in building the pyramids of Egypt; for, in that short space of time, millions of pounds of water go over the falls, and each pound, by the velocity it gains in first falling down the rapids, and then perpendicularly, acquires resistless energy. Water falling one hundred feet would strike on every square foot with a force of more than six thousand pounds."

PNEUMATICS;

OR,

THE MECHANICAL PROPERTIES OF AIR.

THE earth which we inhabit is entirely enveloped, or surrounded, by a thin, transparent, and invisible fluid, called *air*. This air, together with the various gases, steams, vapors, and exhalations that are constantly thrown into it, and which form clouds, is called by the general name of the *atmosphere*. Consequently, atmospheric air is of a very mixed nature; but when pure, it is found, by chemical examination, to consist of two permanently elastic gases, or airs, called ***nitrogen***

and *oxygen*, as we shall hereafter show in our chapter on Chemistry.

Air, though invisible, is a material substance, and partakes of all the properties which belong in common to other matter; for it occupies space, attracts and is attracted, and, consequently, has weight. It likewise partakes of the nature of fluids, for it adapts itself to the form of the vessel which contains it; and it presses equally in all directions; consequently, it must be considered as a material fluid. But, inasmuch as it is highly elastic, a property which is common to all gases, steams, and vapors, while the more visible and tangible fluids, such as water, oil, spirits, &c., possess this character in a very slight degree, if at all, so they require a separate examination.

The various airs, or gases, are called *permanently elastic*, because, under all changes which can be wrought upon them, they maintain their characters of fluidity and elasticity, and will not admit of being congealed, or rendered solid. With steams and vapors, the case is very different; for they arise from inelastic fluids by the application of heat, and they are highly elastic so long as they retain their form of vapor; but on being cooled, they return again to their original state of inelastic fluid, and therefore differ very materially from air, and cannot be said to be permanently elastic. Water affords a very good instance, for this is inelastic; but its steam is elastic in the highest degree; whenever this steam becomes cooled, it reverts back into its original state of water, and of course resumes all its former characters.

Since air has weight, and every thing upon the earth

is surrounded by it, it follows that all things must be subject to the pressure which will be exerted, not only upon them, but upon itself; and since air is elastic, or capable of yielding to pressure, so, of course, the lower part of the atmosphere will be more dense, or in a state of greater compression, than that which is above. Suppose, for example, that the whole height of the atmosphere is divided into 100 equal parts, and that each of these may weigh an ounce, or may be equivalent to the production of that pressure; then the earth, and all things upon its surface, will be pressed with the whole 100 ounces; the lowest stratum of air will be pressed by the 99 ounces above it, the next by 98, and so on till we arrive at the 99th stratum from the bottom, which will, of course, be subject to no more than one ounce of pressure.

Springs of metal, or wood, expand or contract, until they arrive at a state of equilibrium with the force that is acting upon them. The air acts in the same way; for, being of an elastic nature, it will, of course, yield to any force that may be impressed upon it, until its spring becomes a balance to that force. It is on this account alone that we are insensible of the air's pressure; for, notwithstanding the body of a man of ordinary stature is calculated to sustain no less a pressure of air than 32,400 pounds, yet the spring of the air contained within the body exactly balances, or counteracts, the pressure from without, and makes him insensible of the existence of any pressure at all. The spring and pressure of air will thus balance each other in all cases, except when the communication is cut off, and the natural equilibrium is destroyed by some disturbing cause.

The air-pump is the instrument that is generally used for the destruction of this equilibrium; for, by means of this machine, the air may be taken from the interior of vessels which are put upon its plate, and then the effects of the external and undisturbed air immediately begin to show themselves. Thus, for example, if a small glass receiver, which is open both above and below, be placed upon the plate of an air-pump, and the palm of the hand be put upon it, so as to cover it completely, without leaving any orifice for the admission of the external air,—as soon as the pump is set in motion, the hand will be forcibly held down to the receiver, and cannot be released without difficulty; for the air within the glass being rarefied or diminished in quantity, that without will preponderate by its weight, which keeps the hand down, while the spring of that air which is contained in the hand will cause its lower side to swell, and enter the glass to a considerable depth. This shows the necessity of having all glasses, to be used upon the air-pump, with hemispherical or rounded tops, that they may present a dome, or arched form, to the pressure of the external air; and all such glasses are called by the general name of *receivers*. If an open-topped receiver be covered with a piece of flat glass, the pressure from without will break it.

If a small portion of the shell of an egg be broken away at the small end, and it is then placed under a receiver, and the air is exhausted, the bubble of air that is always contained in the large end will expand, and force out the contents of the egg. A withered apple, placed under a receiver, will expand, and appear fresh, provided its skin be not broken. That air is

contained in water appears plain from the following experiment: Place a tumbler of clear water, in which not a single bubble of air is visible, under a receiver, and then exhaust it; the water will instantly appear full of bubbles, which become large, and rise to the top; but as soon as the air is returned into the receiver, they are all instantly compressed, and disappear.

The ascent of water in a common pump is caused by atmospheric pressure; for the water in the pump being raised by the action of the upper pump-box, a vacuum is created below, which is immediately filled by the pressure of the air from without, which forces the water in the bottom of the well upward, to supply that vacuum. But, as equal weights must, of course, exactly balance each other, and as the weight of the atmosphere is limited, it is evident that only a column of water of a certain height can be raised by that weight. Accordingly, it has been found that water cannot be raised in a pump, by the mere pressure of the external air, higher than 32 or 33 feet; whence the inference is plain, that a column of water of this height is exactly equal in weight to that of the atmosphere on the same surface. The diameter of the column of water, in this case, is of no consequence; because, whatever it may be, an equal-sized column of air always acts against it.

This balance of power between a perpendicular column of water and atmospheric pressure was first observed by Galileo, in erecting a pump for the grand duke of Tuscany; but he appears not to have been aware of its cause. This was first investigated by Torricelli, who made use of quicksilver, a fluid 14

times heavier than water, by which he was enabled to produce a pressure equal to that of water with one fourteenth part of its height, and accordingly, his experiments were very neat and accurate. He filled glass tubes of different sizes, having one end closed with quicksilver; and then, by covering the open end, he inverted them into basins filled with the same metal. Thus he found that the diameters of the tubes had no effect on the experiments, but that all those which were less than 28 inches in height, remained full of quicksilver, when inverted, and that in all those which were taller, the quicksilver descended until it became stationary at between 28 and 31 inches above the surface of that which was in the basin. An empty space was thus left at the upper end of the tube, which has since been found to be the most perfect vacuum producible by art. This is known by the name of the *Torricellian vacuum.*

A tube filled with quicksilver, and thus disposed, is called a *barometer.* In this instrument, the column, being maintained by the pressure of the air, must of course be a balance to that pressure; and if the amount of pressure changes, as it is found to do, then the height of the mercurial column will change also. It is on this account that the quicksilver in the barometer moves up and down through a space of three inches, because the density of the air is never so great as to cause it to sustain the quicksilver at more than 31 inches from the surface of that in the basin below, nor does it ever diminish so as to allow the column to descend lower than 28 inches. The falling of the mercury in the barometer always indicates that a

storm is approaching; for this fall takes place in consequence of the rarefaction of the air, which presently causes the surrounding air to rush in to restore an equilibrium. The barometer thus becomes a most invaluable instrument to the mariner; for on many occasions, when the weather is perfectly serene, and the sky exhibits not the smallest token of approaching bad weather, the mercury is seen to sink with uncommon rapidity. The prudent seaman immediately takes in sail, and makes every preparation against the coming danger. Scarcely has the ship been put into the condition which the sailors emphatically call "snug," when a squall, or perhaps a hurricane, bursts from the sky, and tears away the sails, although furled and secured to the yards, disabling spars and masts, and, but for the timely preparation made against it, would have rendered the ship a complete wreck.

Another useful purpose to which the barometer is made subservient, is to measure the height of mountains; for as the mercurial column is always an exact indication of the pressure produced by the mass of air above its level, the mercury must fall when the instrument is carried from any lower to any higher situation, and the degree of falling must always tell exactly how much air has been left below. When the barometer, on the surface of the earth, stands at 30 inches, and the temperature is 32 Fahrenheit, it has been ascertained, by trial, that taking such a barometer to the perpendicular height of 87 feet lowers the quicksilver just one tenth of an inch. But as the atmosphere decreases in density and weight as we ascend, something more than 87 feet must be ascended, to lower the mercury

another tenth, and so on. By nice calculations of this sort, the system of measurement has been brought to such perfection, that the height of any accessible mountain may be ascertained with the utmost accuracy.

That water is at all times contained in air is evident from the cloud of vapor which we constantly observe to be precipitated whenever a very clear receiver is exhausted upon the air-pump, and which is neither more nor less than a shower of rain in miniature. The damp on our walls and windows, which precedes wet weather, arises from the same cause; for then the air is overcharged with water, and begins to return a part of it: the pressure of water in the atmosphere is detected by the instruments called *hygrometers*, which measure the moisture of the air. They are of various forms, and are constructed of different materials; but, unfortunately, most of them lose their action in course of time. One of the simplest of these instruments may be formed of a considerable length of well-twisted flaxen string, suspended from the ceiling of a room about 4 inches from the wall, and stretched tight by a leaden ball, above which is fixed a circle of pasteboard with divisions upon the edge of it, and a fixed mark on the wall for observing their motion. In wet weather the string twists tighter, and of course turns the circle round, and in dry weather it uncoils. There is a toy called the *weather-house*, constructed on this principle: in this, by the twisting and untwisting of the string, a woman comes out at the door in fine weather, and a man when it is wet. The most common hygrometer, which somewhat resembles a watch

in shape, is made of the beard of a peculiar species of wild oat, which possesses the singular property of coiling up in dry weather, and unfolding when wet. A scale-beam, with any substance capable of absorbing moisture, such as a sponge, at one end, counterpoised by a metal weight at the other, becomes an hygrometer — since the sponge will absorb moisture from the air, and become dry again, by which it is made heavier or lighter than the counterpoising weight.

Air incorporates not only with water, but with a great variety of other volatile materials, by which many of its characters become much changed; and since heat assists in these combinations, so all warm or hot fluids will evaporate more readily than such as are cold. Put a few drops of ether into a large drinking-glass, and cover it with a plate for a few minutes, the ether will evaporate into the air, and will render it so inflammable that it will take fire on the approach of a taper. Notwithstanding the attraction that thus appears to exist between the air and various fluids, yet the very pressure of the atmosphere prevents their rising in vapor, or evaporating, upon a slight increase of temperature. Thus ether is the rarest and most volatile of all the visible fluids; and when a cup containing a little of this is placed under the receiver of an air-pump, a very trifling action of the pump will make it boil. Water in the open air will not boil unless heated to 212 degrees, but when the atmospheric pressure is removed, it boils at a much lower temperature; and a glass of strong ale, when heated in the slightest degree under an exhausted receiver, will put on the appearance of boiling. From these facts it follows that,

on the top of a mountain, water will boil with a less degree of heat than in a lower region; and this has been verified by actual experiment.

From the highly elastic nature of air, there is no limit to its condensation, which may be continued as long as there is strength in machinery to force it. It has been carried to great extent; but, from all the experiments that have been tried, it does not appear that condensation produces any effect on the fluidity, transparency, or other characters, of air. Various machines have been invented for this purpose. The air-gun is the best example of the surprising force which air is capable of exerting when condensed to a considerable degree; for by means of this instrument, bullets may be propelled with a force very nearly equal to that of gunpowder. It is a curious fact, that, although the air-pump is a modern invention, yet the air-gun, which is so nearly allied to it in the construction of its valves and condensing syringe, existed long antecedent to it; it was invented as early as the year 1408. The air-gun of the present day, however, is very different from that of former times, which discharged but one bullet after a long and tedious process of condensation, while it now discharges five or six without any visible diminution of force, and will even act upon a dozen, though with less effect.

The alternate rarefaction and condensation of the atmosphere is the cause of most of the changes of the weather; for thus are produced not only wind and storms, but dew, fog, rain, hail, and snow. The air, being saturated with moisture, lets fall a part of it on any reduction of the temperature: the atmosphere,

which has been heated by the sun during the day, and has received much moisture, lets it fall again during the night, and thus causes the night fogs of certain seasons, which float near the surface of the earth until again acted upon by the beams of the next morning's sun. Fog, when condensed by the combination of the minute particles, forms rain; and rain, when frozen, becomes snow or hail.

The general principles of *aërostation*, or navigating the air in balloons, are so little different from hydrostatics, that the reader may be supposed already to understand them, from what has been said. It is a fact universally known that, when a body is immersed in any fluid, if its weight be less than an equal bulk of that fluid, it will rise to the surface; but if heavier, it will sink; and if equal, it will remain stationary. For this reason smoke ascends into the atmosphere, and heated air into that which is colder. The ascent of the latter is shown in a very easy and satisfactory manner, by bringing a red-hot iron under one of the scales of a balance; the balance is instantly made to ascend; for as soon as the iron is brought under the scale, the hot air, being lighter than that which is colder, moves upward, strikes the scale, and elevates it. Upon this simple principle depends the whole theory of aërostation; for it is the same thing whether we render the air lighter by introducing a quantity of heat into it, or enclosing a quantity of gas, specifically lighter than the common atmosphere, in a certain space; both will ascend, and for the same reason. The power of hot air, in raising weights, may be shown in the following manner. Roll a sheet of paper into a conical form,

and fasten it, by its apex, under the scale of a balance; apply the flame of a candle underneath, and the scale will rise, and will not be brought into an equilibrium with the other, except by a much greater weight than would be imagined by a person who had never seen the experiment.

The first balloon was made by a man ignorant of what he was about to discover. Seeing the clouds float high in the atmosphere, he thought that, if he could make a cloud and enclose it in a bag, it might rise, and carry him with it. Then, erroneously supposing cloud and smoke to be the same, he made a fire of green wood, and placed a great bag over it, with the mouth open. He soon had the joy of finding himself in the possession of a bag-full of smoke, which presently rose to the ceiling of the room; but he understood not that the cause of its rising was the hot, rarefied air within, which, being lighter than the surrounding air, was buoyed up, while the visible part of the smoke, which chiefly engaged his attention, was really heavier than the air, and impeded the ascent of the bag. The hot air or fire balloon was afterwards better understood, and was used by aëronauts, until the more commodious and less dangerous modification, called the *inflammable air balloon*, or *balloon of hydrogen gas*, was substituted. The first aëronautic expeditions astonished the world, and endless speculations were indulged as to the important uses to which the new discovery might be applied; but more mature reflection, and recent trials, have shown that the balloon is interesting chiefly as a philosophical toy, and as having furnished the means of making some observa-

tions in elevated regions of the atmosphere. An aëronaut may rise or descend in the air, by throwing out ballast or letting off gas; but he has no power of producing a lateral motion.

The *diving-bell* is a large, heavy, open-mouthed vessel, which is let down in the water, bottom upwards, with men inside. The enclosed air keeps out the water at first; but as the bell descends, the pressure of the water increasing according to its depth, the air is compressed within the bell, and, at 34 feet depth, it is reduced to half its bulk. The bell is then half full of water, and a person within breathes twice as much air, at an inspiration, as he does at the surface. When men are required to remain long under water, a supply of fresh air is conveyed down by means of a forcing-pump, and the heated and contaminated air, which has served for respiration, and which rises to the top of the bell, is allowed to escape through an opening. Men can work at a distance from the bell, and breathe the air from it, through tubes of communication. These operations are so little hazardous, or uncomfortable, that the wages of submarine labor are very little higher than any other.

OPTICS.

Luminous Insects.

THIS science treats of the phenomena of *light* and *vision*. Of the precise character of light there are various theories, but none which admit of actual dem-

onstration, or proof. By some, it has been described as consisting of very minute particles, which are thrown off from what are called *luminous* bodies, in all directions, and with immense velocity; while others consider it as the effect of an undulation, or vibration, produced by luminous bodies in the thin and elastic medium which is interposed between them and the seat of our vision; this vibration producing an effect upon our organs, which we recognize as light, analogous to the impression of sound upon the ear, caused by the atmosphere. This theory is called the *undulatory* theory of light; and the former one, in which light is supposed to consist of material particles, is called the theory of *emission*. Whatever may be the cause, or absolute nature, of light, we know it is a remarkable property of luminous bodies; that it enables us to see the luminous objects themselves, as well as others; and that its absence produces darkness.

All visible bodies may be divided into two classes—*self-luminous* and *non-luminous*. Under the first head are comprised all those bodies which possess in themselves the property of exciting the sensation of light, or vision; such as the heavenly luminaries, terrestrial flames of all kinds, phosphorescent bodies, and those substances which shine by being heated, or by friction. Under the second class, we recognize such bodies as have not, of themselves, the power of throwing off particles or undulations of light, but which possess the power of reflecting the light which is cast upon them by self-luminous bodies. A non-luminous body may thus, by reflection, receive light from another non-luminous body, and communicate it to a third, and so

on; all reflected light, however, is inferior, in point of brilliancy, to that which comes direct from a self-luminous body. The transmission of light was formerly supposed to be instantaneous; but recent observations have shown that, like sound, it requires a certain time to pass from one place to another, though the velocity of its motion is truly astonishing, as has been manifested in various ways. Astronomers have proved, by observing the eclipses of Jupiter's satellites when that planet is nearest, and when it is farthest, from the earth, that light moves from the sun to the earth, a distance of 95 millions of miles, in seven and a half minutes, or about 200,000 miles during a single vibration of a pendulum! So prodigiously great is this velocity, that, as far as any of the common affairs of life may be concerned, light may be said to be instantaneous in its universal action.

Light proceeds in a straight direction from the luminous body which produces it. The direct shining of the sun, or any other luminous body, is in the form of *rays*, or thin, ethereal lines, each acting independently of the other. No such separation of parts, however, is observable in common circumstances, in consequence of the diffusive properties of our atmosphere. *Seeing* is simply the reception of the direct or reflected ray from an object, by our eye. Until the rays of the sun reach the spot on which we are placed, we are neither conscious of light, nor of the presence of the sun as an object. In the same manner, a candle, being lighted, and exposed in the open country in a dark night, all who are able to see it are within the influence of its rays; but beyond a given distance,

these rays are too weak to produce vision; and all who are in this remote situation cannot see the smallest appearance of the light. Yet the number of rays which proceed even from a common candle is so vast as to be beyond the power of imagination to conceive; for if such a light is visible within a sphere of 4 miles, it follows that, if the whole of that space were surrounded with eyes, each eye would receive the impression of a ray of light. In proportion as light advances from its seat of production, it diminishes in intensity. The ratio of diminution is agreeable to that which governs physical forces; that is, the intensity of the light will diminish as the square of the distance increases, or at the rate of 1, 4, 16, &c. But, in proportion as we lose in intensity, we gain in volume; the light is the weaker the farther it is from the candle, but it fills a wider space.

In discussing the properties of light, it is important to consider the *medium* through which it passes, as air, water, glass, &c. Any parcel of rays passing from a point, is called a *pencil* of rays; the point at which converging rays meet, is called a *focus*. Rays may be *parallel*, *convergent*, or *divergent*, which terms will not require an explanation. The point towards which they tend, but which they are prevented from reaching by some obstacle, is called the *imaginary focus*.

Refraction is the bending of rays of light from the course they first pursued. If the rays, after passing through a medium, enter another of different density, perpendicular to its surface, they are not refracted, but proceed through this medium, in their original direction. For instance, if the rays of the sun were to

strike upon the surface of a river at right angles, or perpendicularly to its surface, they would go straight to the bottom, and the line which they pursued in the air would be continued in the water. But if they enter obliquely to the surface of a medium either denser or more rare than what they moved in before, they are made to change their direction in passing through that medium; in other words, they are *refracted*. The mode of refraction depends on the comparative density or rarity of the respective media. If the medium which the rays enter be denser, they move through it in a direction nearer to the perpendicular drawn to its surface. On the contrary, when light passes out of a denser into a rarer medium, it moves in a direction farther from the perpendicular. This refraction is greater or less; that is, the rays are more or less bent, or turned aside, from their course, as the second medium, through which they pass, is more or less dense than the first. To prove this in a satisfactory way, take an upright empty vessel into a darkened room, which admits but a single beam of light obliquely through a hole in the window-shutter. Let the empty vessel stand on the floor a few feet in advance of the window which admits the light, and let it be so arranged that, as the beam of light descends towards the floor, it just passes over the top of the side of the vessel next the window, and strikes the bottom on the side farthest from the window. Let the spot where it falls be marked. Now, on filling the vessel with water, the ray, instead of striking the original spot, will fall considerably nearer the side towards the window. And

if we add a quantity of salt to the vessel of water, so as to form a dense solution, the point where the rays strike the bottom will move still nearer to the window. In like manner, if we draw off the salt water, and supply its place with alcohol, the beam of light will be still more highly refracted; and oil will refract yet more highly than alcohol.

The following simple experiment is well known: Take an empty basin, and place it on a table; then lay a silver dollar at the bottom of the basin, and let the spectator withdraw so far that the brim of the basin hides the dollar. Now, fill the basin with water, and the dollar, though lying unmoved, will come completely into sight. The explanation of this phenomenon is, that the ray of light producing vision in the eye is bent, as it emerges from the water, and has all the effect of conveying our sight round a corner. The refractive power of water is also observable when we thrust a straight stick into it; we see that the stick seems to be bent, and fails in reaching the point which we desired it should. On this account, the aim, by a person not directly over a fish, must be made at a point apparently below it, otherwise the weapon will miss, by striking too high. With regard to the refractive power of transparent substances, or media, the general rule, with certain limitations, is in proportion to the densities of the bodies; it increases, for instance, from the most perfect vacuum which can be formed, through air, fresh water, salt water, glass, and so on. But those substances which contain the most inflammable matter have the highest refractive power. It was from the great refractive powers of the diamond

and water, that Newton, with admirable sagacity, predicted that they contained inflammable principles.

The refraction of rays of light is observable in the case of common window-glass. The two sides of a pane not being perfectly parallel to each other, bodies seen through it appear as if distorted; and as the obliquities in the glass are very various, the distortions are equally grotesque and numerous. Some windows are purposely ground on the surface, to produce universal and minute refraction; and thus so great a confusion is introduced among the rays, that objects are not distinguishable through the glass. When the obliquities on the surface of one side of a piece of glass stand distinct from each other, so as to admit of refraction in a clear and distinguishable manner, then each obliquity affords a separate view of an object on the opposite side, and thus an object seems to be multiplied as many times as there are obliquities. The refraction of light is also observable, on a great scale, in relation to our atmosphere. The rays of the sun, on reaching the confines of the atmospheric fluid which envelops the earth, enter a medium of greater density than that through which they have previously passed, and consequently are refracted, or bent. One obvious effect of this is, that we never see the sun in the actual position which he occupies. He always appears more or less raised in relation to our eyes, as was the case with the dollar in the above-described experiment of the basin of water. This is peculiarly the fact in the morning, when his earliest rays meet our eyes. Entering a denser medium, these rays bend round to meet our vision, and we actually see the body of the sun a few minutes before he has

risen above the horizon; like the dollar in the basin, we see him round a corner. In proportion as the sun approaches the zenith, the refraction diminishes; and as he recedes toward setting, it increases. So considerable is it, in the hazy atmosphere of evening, that we retain a sight of the sun's disk after it has sunk. The same phenomena occur in relation to the other heavenly luminaries.

From these explanations, it will appear that the directness of our vision is at all times liable to be disturbed by atmospheric conditions. So long as the atmosphere between our person and the object we are looking at is of the same density, we may be said to see in a straight line to the object. But if, by any cause, a portion of that atmosphere is rendered less or more dense, the line of vision is bent, or refracted, from its course. A thorough comprehension of this truth in science has banished a mass of superstition. It has been found that, by means of powerful refraction, objects at great distances, and round the back of a hill, or considerably beneath the horizon, are brought into sight. In some countries this phenomenon is called *mirage.* The following is one of the most interesting and best-authenticated cases of the kind. In a voyage performed by Captain Scoresby, in 1822, he was able to recognize his father's ship, when below the horizon, from the inverted image of it which appeared in the air. "It was," says he, "so well defined, that I could distinguish, by a telescope, every sail, the general rig of the ship, and its particular character, insomuch that I confidently pronounced it to be my father's ship, the Fame, — which it afterwards proved to be, — though,

on comparing notes with my father, I found that our relative position, at the time, gave our distance from one another very nearly thirty miles, being about seventeen miles beyond the horizon, and some leagues beyond the limit of direct vision!"

Dr. Vince, an English philosopher, was once looking through a telescope at a ship which was so far off, that

he could only see the upper part of the masts. The hull was entirely hidden by the bending of the water; but, between himself and the ship, he saw two perfect images of it in the air. These were of the same form and color as the real ship; but one of them was turned completely upside down.

In the sandy plains of Egypt, the mirage is seen to great advantage. These plains are often interrupted by small eminences, upon which the inhabitants have built their villages in order to escape the inundations of the Nile. In the morning and evening, objects are seen in their natural form and position; but when the surface of the sandy ground is heated by the sun, the land seems terminated, at a particular distance, by a general inundation; the villages which are beyond it appear like so many islands in a great lake; and an inverted image of a village appears between the hills.

The Swedish sailors long searched for a supposed magic island, which, from time to time, could be descried between the Island of Aland and the coast of Upland. It proved to be a rock, the image of which was presented in the air by mirage. At one time, the English saw with terror the coast of Calais and Boulogne, in France, rising up on the opposite side of the Channel, and apparently approaching their island. But the most celebrated example of mirage is exhibited in the Straits of Messina. The inhabitants of the Calabrian shore behold images of palaces, embattled ramparts, houses, and ships, and all the varied objects of towns and landscapes, in the air — being refracted images from the Sicilian coast. This wonderful phenomenon is

regarded by the common people as the work of fairies, and is known by the name of the *fata morgana.*

Color by Refraction. One of the most remarkable phenomena attending refraction, is, that the rays of light, which seem to us to be white, may be separated into rays of various colors. It will be obvious that light has the effect of representing colors when no color substantially exists, by noticing the glancing and varied hues on irregular surfaces of glass, ice, or other crystallized substances. The proper method of analyzing the rays of light, and discovering into what colors they may be resolved, is by the use of a *prism*, or three-sided rod of glass. The experiment may be made in the following manner: Into a darkened room admit a beam of sunlight through a hole in the shutter; let this fall upon the prism, and, instead of passing in a direct line through it, and forming a circular white spot upon the wall opposite, the rays will be refracted upwards, and form an oblong image upon the wall, divided into seven colors — red, orange, yellow, green, blue, indigo, and violet. This lengthened image of the sun is called the *solar* or *prismatic spectrum.* No lines are seen across the divisions between the different colors, and it is extremely difficult for the sharpest eye to point out their boundaries. This experiment shows that common white light is compounded of seven different colors, and that they all differ in their powers of refraction; that is, the glass, or whatever medium through which they pass, attracts no two of them with the same degree of force. As they differ in refraction, so also they differ in their powers of *reflection;* and hence arise all the various colors of bodies. Those bodies

which reflect only the red rays, for instance, and absorb all the others, appear red; and so of the other colors. Those which reflect all the rays appear white, and those which absorb all the rays, or nearly so, appear black. Hence it is that black clothes are warmer than any other color, as they absorb more light, and light is never unaccompanied by heat. On the other hand, white is the coolest dress that can be worn.

The *rainbow* is formed by a combined process of reflection and refraction. It is never seen, except when rain is falling between the spectator and the sky opposite the sun. If we look into a globe of glass, or water, held above the head, and opposite to the sun, we shall see a prismatic spectrum reflected from the farther side of the globe. In this spectrum, the violet rays will be innermost, and the spectrum vertical. If we hold the globe on a level with the eye, so as to see the sun's light reflected in a horizontal plane, we shall see a horizontal spectrum with the violet rays innermost; and a corresponding variation will be observed in other positions. Now, since, in a shower of rain, there will be drops in all positions relative to the eye, the eye will receive spectra inclined at all angles to the horizon; so that, when combined, they will form the large, curved spectrum called the *rainbow*. In a very strong sunlight, a *secondary* bow is seen outside of the primary one: the colors are fainter, because the bow consists of rays that have suffered two reflections instead of one. Red rainbows, distorted rainbows, and inverted rainbows on the grass, have been observed. The latter are formed by the drops of rain suspended on the spiders' webs in the fields.

Light is diffused around us by the refractive power of the atmosphere, and therefore objects are quite visible, though the rays of the sun do not strike directly upon them. The atmosphere being thus a vehicle of light, it may be supposed that, if we were to ascend to a great height above the level of the earth, or beyond the atmosphere, we should be almost in darkness, although we were, in reality, nearer the sun. There is reason to believe that such would be the case; for travellers, who have ascended to the summit of Mont Blanc, or about 15,000 feet above the level of the sea, mention that, at that height, the sky appears to be of an exceedingly dark blue color, or almost black, and the light so faint that the stars are visible. We may understand, from this, that the rays of the sun travel through immense regions of darkness before they reach our atmosphere, and are diffused into that universal, soft light which we observe around us.

Reflection adds to the brilliancy of the great mass of light transmitted from the sun. If all the objects on the surface of our planet were black, which is a negation of all color, the sun's light would be absorbed, and we should, even while the sun shone, possess much less light than we now enjoy. But, in consequence of the varied coloring in which our earth is dressed, the sun's rays are more or less reflected, and sent back into the general mass of light. If the object on which the rays fall be clear, and polished on its surface, it will possess the power of representing the image of any object within the reach of its rays. Thus the surface of a smooth lake will represent the image of the sky above, of the neighboring hills, or of any

object floating on its surface. But the phenomena of reflection are too familiar to the reader, to require any very minute description.

A *lens* is a thin piece of glass, or any other transparent medium, having one or both sides either convex or concave. The convex surface magnifies objects, and the concave diminishes them; for, according to the laws of refraction already explained, the rays of light, falling upon a convex lens, are refracted towards its centre, or drawn to a focus; and as the eye judges of the position of an object from the direction in which the rays last proceed, the converging rays will appear to come from a wider extent of space than is real. In a concave lens, the rays, being refracted in a different direction, diverge, instead of converging, and strike the eye as if coming from a narrower space than the reality; for this reason, the apparent size of the object is diminished. Concave mirrors magnify, and convex mirrors reduce objects, on the same principle. The human eye contains a natural convex lens, through which all the rays of light which cause our vision pass, and are brought to a focus on the *retina*, a delicate membrane, lining the back part of the eye; this is connected with the optic nerve, which communicates with the brain — the organ, or centre, of all sensation.

ACOUSTICS.

The term Acoustics is derived from a Greek word which signifies, *to hear*, and is applied to that branch of natural philosophy which treats of the nature of *sound*, and the laws of its production and propagation.

Atmospheric vibration is allowed to be the cause of sound. For instance, a bell is struck by its clapper; the body of the bell consequently vibrates, as we may assure ourselves by applying one of our nails lightly to the edge: in its agitation, it beats, or makes impulses upon the air, which, yielding under the stroke, or pressure, is compressed, or condensed, to a certain distance around. The compressed air instantly expands, and, in doing so, repeats the pressure on the air next in contact with it, and thus each one of the original strokes of the vibrating metal sends out a series of *shells* of compressed air, somewhat like the waves dispersed over a lake from the dropping of a stone into its placid bosom, and, like them, always lessening in bulk and force. These shells are from 2 inches to 30 feet in thickness. The air they agitate finally reaches the ear, where it gives a similar impulse to a very fine nervous membrane, in the ear, called the *drum*, which communicates with the auditory nerve, and this conveys to the brain the sensation of sound.

With regard to the velocity with which the impulse

of sound advances, it appears, from the most accurate experiments, on the discharge of pieces of ordnance, and marking the interval between the flash and the report, at a distance carefully measured, that, when the atmosphere is at the temperature indicated by 62° of Fahrenheit, sound travels at the rate of 1125 feet per second, which is nearly equal to the velocity of a cannon-ball, the moment it issues from the piece. The ball is very speedily retarded by the resistance of the air, but the sound advances with undiminished velocity, though unequal intensity. It will travel a mile in little more than four seconds and a half, or twelve miles and three fourths a minute.

On this depends an easy method of determining, in many cases, our distance from objects, and which may often prove useful, particularly in thunder-storms. We have only to observe, in seconds, the interval between the flash and the report, and allow four seconds and a half to every mile, or 1125 feet to every second. It is remarkable, also, that all kinds of sounds, strong or weak, acute or grave, advance with the same velocity; and this arises from the circumstance, that all the oscillatory movements in the air, however minute or extended, are performed each in the very same interval of time. For every degree of Fahrenheit above 62°, the velocity of sound is increased one foot and about a seventh; and for every degree below 62°, it is lessened in the same measure; so that, when the temperature is at the freezing point, the rate is only 1090 feet per second.

That water is a vehicle of sound, as well as the air, is proved by various circumstances, particularly by the

fact, that a bell rung under the water can be heard above; and if the head of the auditor be also under water, it will be still more distinctly heard. The sound which the sonorous body produces, however, is graver than that which it gives forth in the air. That the atmosphere is necessary for the transmission of sound is evident from the fact, that a bell rung in the exhausted receiver of an air-pump can scarcely be heard. Smooth bodies form favorable channels of sound; as, for example, the surface of ice, snow, water, or the hard ground. Savages, it is well known, are in the habit of putting their ear to the ground in order to discover the approach of enemies, or beasts of prey.

Tubes convey sounds with great accuracy, and to great distances; and this property has been applied to various useful objects. The most valuable of these purposes is that of examining the chests of persons supposed to possess pulmonary affections. This is done by means of the *stethoscope*, an instrument which resembles a small trumpet. The wide end of the instrument is applied to the body, and the other is held to the ear by the physician, who then has a very clear perception of the sounds caused by the action of the lungs, and can judge whether they be healthy or the reverse. A person of skill can exactly describe the condition of the lungs, from the nature of the sounds that thus reach his ear.

In a public exhibition in London, there has long been shown an apparatus, consisting of a four-footed stand, and several trumpet-mouthed tubes, from any one of which a spectator will receive a ready answer to a question. The answer is said to come from the "in-

visible girl;" and the true explanation of the puzzle is, that a secret tube, in the legs of the apparatus, communicates the sounds to a girl in a neighboring apartment. Sound requires a certain length of time to travel from one place to another.

It is on account of this principle that, in long ranks of soldiers, where two bands of music are placed at a considerable interval from each other, it is impossible for the two bands to keep time. They may, indeed, play together, but each soldier will hear the nearest sounds quickest, and thus they will seem to be out of time. It is often noticed, too, that if, from an eminence, we look upon a long column, which is marching to a band of music in front, the various ranks do not step exactly together. Those in the rear are, in each step, a little later than those before them. This produces a sort of undulation in the whole column, which is difficult to describe, but which all who have noticed it will understand. Each rank steps, not when the sound is *made*, but when, in its progress down the column, at the rate of 1125 feet per second, it reaches their ears. Those who are near the music hear it as soon as it is produced, while the others must wait till sufficient time shall have elapsed for it to have passed through the air to them.

Should a commander stand at a distance of a fifth of a mile from his army, and command them to fire, they might all obey at the moment when the word of command reached them; but the officer will hear the report of the guns from those at the side nearest him first, then those a little farther off, and so on to the most remote. Thus, though all might obey with equal

alacrity, the sounds will not, and cannot, appear simultaneous, for the report of the distant guns must be delayed long enough for the command to pass from the officer to the men, and then for the sound to return. All attempts, therefore, to make the firing appear exactly simultaneous from a long line, must be in vain.

An *echo*, or duplication, of sound, is one of the most interesting phenomena in acoustics. The cause of it is precisely analogous to the reaction of a wave of water. When a wave of water strikes the precipitous bank of a river, it is thrown back in a diagonal direction to the side whence it came, and then again strikes on the bank. In the same manner, the pulses, or waves, of sound are reflected, or thrown back, from flat surfaces which interrupt them, and, thus returning, produce what we call an *echo*. It is evident that the smoother the surface which reflects the sound, the more perfect will be the reverberation. An irregular surface, by throwing back the wave of sound at irregular intervals, will so confound and distract it, that no distinct or audible echo will be reflected. On the contrary, a regular concave surface will be concentrated into a focus capable of producing a very powerful effect. The velocity with which an echo returns to the spot where the sound originates, depends, of course, upon the distance of the reflecting surface; and since sound travels at the rate of 1125 feet in a second, a rock situated at half that distance will return an echo in exactly one second. The number of syllables which we pronounce in a second will, in such a time, be repeated distinctly, while the end of a long sentence would blend with the commencement of the echo.

An echo may be double, treble, or even quadruple, according to the nature and number of the projecting surfaces from and to which the sound is allowed to play. Distinctly-marked echoes of this combined and planned order may sometimes be heard in the vaults of cathedrals — in which case, the waves of sound are driven from side to side of a deeply-groined arch, and reverberate in protracted peals. One of the most interesting echoes of this kind in nature is that which occurs on the banks of the Rhine, at Luxley. If the weather be favorable, the report of a musket fired on one side is repeated from crag to crag, on opposite sides of the river alternately.

There are some remarkable echoes in churches, arising from peculiarities in the construction. In erecting the baptistry of the church of Pisa, the architect disposed the concavity of the cupola in such a manner, that any noise from below is followed with a very loud and long double echo. Two persons whispering, and standing opposite to each other, with their faces near the wall, can converse together without being overheard by the company between. This arises from the elliptical form of the cupola, each person being placed in the focus of the ellipsis. In the cathedral church of Gloucester, England, there is, or was, a whispering gallery about the eastern extremity of the choir, which extends from one end of the church to the other. If two persons placed at distant points speak to one another in the lowest voice, it is distinctly heard. A similar effect is produced in the vestibule of the observatory of Paris, and in the cupola of St. Paul's, London. A tourist has mentioned that in Italy, on the

way to Naples, and two days' journey from Rome, he saw in an inn a square vault, where a whisper could easily be heard at an opposite corner, but not at all on the side corner that was near to you. This property was common to each corner of the room. He saw another, on the way from Paris to Lyons, in the porch of a common inn, which had a round vault. When any person held his mouth to the side of the wall, several persons could hear his whisper on the opposite side.

The whispering gallery in St. Paul's, London, is a great curiosity. It is 140 yards in circumference, and is just below the dome, which is 430 feet in circumference. A stone seat runs round the gallery along the front of the wall. On the side directly opposite the door by which visitors enter, several yards of the seat are covered with matting, on which the visitor being seated, the man who shows the gallery whispers, with the mouth near the wall, at the distance of 140 feet from the visitor, who hears his words in a loud voice, seemingly at his ear. The mere shutting of the door produces a sound like a peal of thunder rolling among the mountains. The effect is not so perfect if the visitor sits down half way between the door and the matted seat, and much less if he stands near the man who speaks, but on the other side of the door.

It is of great importance that buildings designed for large auditories should be constructed in such a manner that the voice of the speaker will neither echo from the walls, nor be lost to the hearers. The best-known form of apartment, for the proper distribution of sound, is that in which the length is from a third to a half more than the breadth; the height somewhat greater

than the breadth, and having a roof bevelled off all round the sides. This species of ceiling, technically called a coved or *coach roof*, from its being lower at the sides than at the centre, is, in all cases, best suited for conveying sounds clearly to the ears of auditors.

MUSICAL SOUNDS. There is a peculiar character in sounds, depending on the nature of the sounding body. A blow with a hammer, or the report of a pistol, produces only a noise. But if a body be of such a thinness and tightness as to produce a succession of impulses of a sufficient degree of quickness, a *tone* is the result—namely, a sound composed of a great number of noises, all so close upon each other that they bring but one result to the ear. Wires and strings of metal and catgut, slips of metal, fine membranes, and columns of the air itself, enclosed in tubes, are the most familiar means of producing sounds of this kind. Such sounds are said to be musical.

The study of musical sounds, as a branch of natural philosophy, is calculated perhaps to give as much pleasure to the man of science as music itself can convey to those who are gifted with what are called good ears. The natural character of these sounds, and their relations to each other, are very remarkable; while the relation of the whole to the human mind must be regarded as one of the most interesting proofs of creative design which the entire circle of nature presents.

The principal sounds in music may be said to be only seven in number. There are other five, which may be produced by the voice with some difficulty; but the voice in an untutored condition gives forth only seven. The notes are of different degrees of shrill-

ness, one rising above another, in succession. A person who knows nothing of music beyond having heard another sing or play, and having seen the key-board of a piano-forte, will be ready to say that there are more notes than seven; but there are only seven that are, strictly speaking, various. The voice, or an instrument, may run up into other notes; but all of these are repetitions of the first seven, and identical respectively with them, in all regards except shrillness. In ordinary piano-fortes, there are at least six repetitions of the seven notes, so that the uppermost keys are more piping than the voice of a child, while the lowest rumble like a drum.

The seven notes are named Do, Re, Mi, Fa, Sol, La, Si, or by the first seven letters of the alphabet, in a peculiar arrangement, namely, C, D, E, F, G, A, B.

There are many curious facts connected with the harmonious notes. The *cries* of a city — that is, the scarcely articulate, but often very musical sounds uttered by persons selling things in the streets — generally rise on thirds or fifths, sometimes on octaves; and this, although few of these poor people have ever been taught music. The cry of oysters by women in Edinburgh is always on an octave. Teachers of elocution are always aware that human beings, in general, make such transitions of voice naturally, under the influence of certain feelings. For example, a person indifferently surprised at hearing a friend say, "I was the person who did so and so," will say, "Was it you?" rising only a third at the last word. If greatly surprised, the rise will be a fifth. There may even be so great a degree of astonishment, that the word "you"

may begin on one note and terminate on its octave. The answer, "Yes, it was I!" will show corresponding declensions or falls of voice. We thus see how truly music is a species of natural language. Unquestionably, every shade of human feeling can be represented by successions of its sounds, apart altogether from its words.

With respect to the sounds produced by wind instruments, the effect is caused by the vibration of a column of air confined at one end, and either open or shut at the other. The length of the sounding column determines the nature of the vibrations; but along with the fundamental tone, there are interior and subordinate vibrations. The whole column divides itself into regular portions, equal to the half, the third, and so on, of the longitudinal extent, in the same manner as is the case in stringed instruments. We may observe something similar to these vibrations in the contraction and expansion of a long and very elastic string, to one extremity of which a ball is attached. A spiral spring also shows, and perhaps more clearly, the repeated stretching and recoil. If suddenly struck at one end, it will exhibit not only a vibration throughout its whole extent, but likewise partial ones, which wind, like a snake, along the chain of elastic rings. If the air be struck with great force, the subordinate vibrations sometimes predominate, and yield the clearest and loudest tones. This may be observed in the dying sounds of a bell, which rise one or two octaves, and expire in the acutest note. Upon the degree of force with which the instrument is blown, depends the performance of the bugle-horn, whose compass is very

small, consisting only of the simplest notes. In other wind instruments, the nature of several notes produced depends upon the length and size of the tube, or the positions of the holes in its sides.

In the organ there is a pipe for each note, and wind is admitted from the bellows to the pipes by the action of keys similar to those of a piano-forte. The organ may be played, also, by a barrel, made to turn slowly under the keys, and to lift them, in passing, by means of pins projecting, at certain determinable intervals, from the surface of the barrel. In wind instruments which are furnished with reeds, the tone depends on the stiffness, weight, length, &c., of the vibrating plate, or tongue, of the reed, as well as on the dimensions of the tube, or space, with which it is connected.

ELECTRICITY.

Electricity, from the Greek word *electron*, amber, properly signifies the science which treats of the phenomena of attraction and repulsion produced by the friction of amber, in which substance these phenomena were first observed. As similar appearances, however, were afterwards observed in sealing-wax, glass, and a vast number of other bodies, the term has been extended so as to embrace the operation of this principle wherever it is found. The property exhibited by amber in attracting light bodies was known more than 600 years before Christ; and Thales of Miletus, in endeavoring to account for it, ascribed to this substance the functions of an animated being. Singularly enough, although this property was known to both ancients and moderns, no experiments seem to have been made upon the subject before the 17th century, when Dr. Gilbert discovered that the electrical attraction resided, not only in amber, but in the diamond and many other stones, glass, sulphur, sealing-wax, resin, alum, &c. After this, experiments and researches were made by many eminent men, among whom were Sir Isaac Newton and Dr. Franklin; and the electric phenomena, connected as they are now known to be by certain well-ascertained laws, form together the most complete and important addition to the physical sciences which has been made since the time of Newton.

The simplest and most usual mode of producing electricity is by friction. If we rub a piece of amber with dry fur or woollen cloth, and then hold the amber over any light substance, as small pieces of paper, or the down of a feather, the light body will be attracted by the amber. The same effect will be produced by rubbing the crystal of a watch upon the sleeve of the coat, and still more powerfully by rubbing a glass tube with a piece of dry silk. In this latter case, when the tube is rubbed in the dark, sparks of brilliant light, accompanied with a crackling sound, will be emitted as long as the friction is continued. In like manner, if a dry black silk ribbon, about two feet long, be laid upon a white one of the same length, and be drawn over woollen cloth, or silk velvet, or even between the finger and thumb, they will be found to adhere strongly to each other. In a dark room, the separation of the ribbons will be accompanied with a flash of light, and either of the ribbons, when separated from the other, will attract light substances.

Now, in these three simple experiments, the amber, the glass, and the silk ribbons, have obviously received new properties, which they did not possess before they were rubbed—namely, the property of attracting light bodies, and the property of emitting light in the dark. These properties are called *electrical.* The amber, the glass, and the ribbons, are said to be *excited* by friction. The power of drawing to themselves light bodies is called *electrical attraction*, to distinguish it from the attraction of cohesion, of gravity, and of magnetism. The light emitted in the dark is named the *electric spark*, and the body which is capable of

acquiring these properties is called an *electric.* By rubbing a great number of other bodies with woollen cloth, fur, silk, &c., they are found to exhibit the same properties as amber and glass; while another class of bodies exhibits no such properties. Hence bodies are divided into two great classes — namely, *electrics* and *non-electrics.* The following is a list of electrics arranged in the order of their perfection: glass, the precious stones, amber, sulphur, shell-lac, and all resinous bodies; bituminous substances; silk, wax, cotton, dry paper; dry animal substances, as feathers, wool, hair, parchment, and leather; dry sugar, ice of distilled water, oils, metallic oxides, ashes, dry vegetable substances, and hard stones.

The *electrical machine* consists of a cylinder, or circular plate of glass, mounted in a frame, so that it can be turned rapidly round on its axis by means of a handle. On one side of it is placed a small cushion covered with silk, against which the glass is rubbed during its rotatory motion; and on the other side, a brass or metal tube, resting upon a stand of glass, for the purpose of collecting the electricity generated during the excitation of the cylinder or plate. When this is turned briskly round, the motion will be accompanied by a crackling noise; and if in the dark, streams of bluish light will be perceived directed toward the sharp points with which the metal tube is furnished for the purpose of drawing off the electricity from the glass. This tube may thus be highly charged with electricity, and when removed from the machine, will retain its electrical properties, and will, by simple contact, communicate a portion of its electricity to another

isolated conducting substance, or be discharged by touching one not isolated. If, with a moderate charge, it be touched with the finger, a sensation like the pricking of a needle is felt, accompanied with a faint spark apparently penetrating the finger.

Bodies are either *conductors* or *non-conductors* of electricity. The best conductors are metals and water; the best non-conductors are glass, wax, gum, resin, &c. The quantity of electricity which can be communicated to a perfect conductor is very great, but it appears to have its limit. If, from different sources of electricity, we charge a metallic ball, and so continue to charge, we shall presently find that the ball will discharge itself through the air into the nearest conducting body, when a spark, describing apparently a zigzag course, will be observed. This spark travels with immense velocity, and is accompanied by a very audible sound. If received by the body of a man or animal, it produces through a part or whole of the system an instantaneous muscular contraction, which may be rendered sufficiently strong to cause death, but in more moderation has been used to advantage in some diseases.

Electricity had long been an object of study with men of science, yet little was done towards elucidating the theory of it, when a discovery was unexpectedly made which raised the science to an extraordinary degree of estimation. This discovery consisted in the art of accumulating electricity by means of the *Leyden jar*. In the year 1745, Von Kleist, a German, made an experiment of which he gives the following curious account: "When a nail, or piece of thick brass wire, is put into a small apothecary's phial, and electrified,

remarkable effects follow; but the phial must be very dry or warm. I commonly rub it over beforehand with a finger, on which I put some pounded chalk. If a little mercury, or a few drops of spirit of wine, be put into it, the experiment succeeds the better. As soon as this phial and nail are removed from the electrifying glass, or the prime conductor to which it has been exposed is taken away, it throws out a pencil of flame so long, that, with this burning machine in my hand, I have taken above sixty steps in walking about my room. When it is electrified strongly, I can take it into another room, and fire spirit of wine with it. If, while it is electrifying, I put my finger, or a piece of gold which I hold in my hand, to the nail, I receive a shock which stuns my arms and shoulders. A tin tube, or a man, placed upon electrics, is electrified much stronger by this means than in the common way. When I present this phial and nail to a tin tube fifteen feet long, nothing but experience can make a person believe how strongly it is electrified."

In the above experiment, as the phial was of small dimensions, and as the circumstances essential to its greatest effects were not combined, because they were unknown, the power of the electricity accumulated was inconsiderable: but soon afterwards the art of giving a strong shock was discovered in Holland, because the vessels employed happened to be larger. As it was known that the air, or the particles floating in it, abstracted the power of electrified bodies, so that even insulation was no remedy against their being in a short time deprived of it, the idea occurred to Muschenbroek and some of his friends, that, if the electrified body

were entirely surrounded by a non-conductor, the dissipation of the electricity would in a great measure be prevented. To ascertain this, a quantity of water was put into a bottle, and electrified till it was thought to be fully charged; but here the original design of the experiment was lost sight of by an unexpected result, which absorbed all their attention. One of the performers, happening to hold his vessel in one hand, while he endeavored to disengage it from the conductor with the other, suddenly received a shock which stunned and terrified him in a high degree. In this manner was discovered what still continues to be called the *electric shock*. At this day, it excites a smile to observe the terms in which the shock is spoken of by several of those who first submitted to its effects. Muschenbroek, who tried the experiment with a thin glass bowl, told his friend Reaumur, that he felt himself struck in his arms, shoulders, and breast; that he lost his breath for a time, and did not feel himself well again for two days. He adds, that he would not take a second shock for the whole kingdom of France. In terms almost equally heightened by terror, speaks Allemand. Though he made the experiment with only a common beer-glass, he declares that he lost his breath for some moments, and felt such an intense pain in his right arm, that he was alarmed for the consequences. Other philosophers, however, were found, who had the resolution to take shocks of great intensity; and one of the most hardy wished that he might die by the electric shock, that his death might furnish an article for the Memoirs of the Parisian Academy!

After the art of giving a shock by means of a phial

or jar had been discovered, the art of combining several jars, so as to unite their powers in one discharge, soon followed, and this improvement constituted what is now called a *battery*. It was made by Dr. Franklin, and resulted from his reflections on the phenomenon of the Leyden jar. It had been found that, by coating the outside of the jar with a conducting substance, which communicated by a wire with the person who discharged it, the strength of the shock was exceedingly increased; and that, unless some conducting substance was in contact with the outside of the jar, no charge could be given. Franklin, in accounting for this circumstance, suggested that a charged phial or jar contained no more electricity than before; that as much was lost on one side as was gained by the other; and that, to discharge it, nothing more was necessary than to make a communication between the two sides: the electricity being by this means enabled to regain its equilibrium, that equilibrium was instantly restored, and no signs of electricity remained. He also demonstrated by experiments that the electricity did not reside in the coating, as had been supposed, but in the glass; for after a phial was charged, he removed the coating, and found that, by applying a new one, the shock might be received.

From these facts, Franklin proposed to distinguish the two opposite electrical states by the terms *plus* and *minus*, or *positive* and *negative*. Thus, when a body or surface has more than its usual portion of electricity, it is said to be *positively* electrified; when it has less than its usual share, it is said to be *negatively* electrified. These two conditions exercise a constant

effort to balance each other; and when a communication is made by a conducting substance between two bodies or surfaces, in these conditions, a discharge ensues, and equilibrium is restored. Another theory was broached by M. Du Fay, according to which there are two electric fluids, the one called *vitreous* and the other *resinous*, which attract each other after separation; but the theory of Franklin has prevailed, and the phraseology introduced by him is the only one used in treating of the science.

The preceding view of the subject induced Franklin to suppose that, if the insides of several Leyden jars were connected by means of a conducting substance, and their outsides connected with each other in like manner, they would receive and impart a charge like a single jar; that the shock would be increased in proportion to their number, and thus a battery of any force would be obtained. Accordingly they were soon constructed of sufficient power to kill small animals. Franklin did not stop here, but pursued his researches with a success that astonished the world. In the year 1749, he suggested an explanation of the phenomena of thunder-gusts, and of the *aurora borealis*, on electrical principles. He pointed out many particulars in which lightning and electricity agree; and, in adverting to the power of pointed rods in drawing off lightning, he supposed that, when fixed in the air at the time when the atmosphere was charged with lightning, they might, without noise or danger, draw from it the matter of the thunderbolt into the body of the earth. The manner in which he proposed to bring his speculations to trial was, to erect on the top

of a tower, or other elevated place, a sentry-box, from which might rise a pointed iron rod, insulated by being fixed in a cake of resin. Electrified clouds passing over this would, he conceived, impart to it a portion of their electricity, which would be rendered evident by the sparks it yielded on being touched by any conductor. Philadelphia contained at that time no building which Franklin deemed proper for his purpose; he therefore laid aside the thoughts of realizing his conjecture at that time. But while he thus postponed the completion of his views, they were actually carried into effect in France, and caused incredible surprise and admiration.

Franklin had communicated to his friend Collinson, in England, regular accounts of his experiments and theories; and the latter had communicated them to the public. These publications were widely circulated, and translated into different languages. In France, the principles of Franklin, and several of the experiments by which they were supported, soon became familiar to some of the chief men of science, and his proposed scheme for drawing lightning from the clouds was actually accomplished in the year 1752. A month after this, but before any intelligence of it had reached America, Franklin himself had demonstrated the truth of his theory by an invention of his own. He prepared a silken kite, with a pointed iron at the top, communicating with the string, to which, at the lower end, was attached a key. Having raised the kite into the air while a thunder-storm was approaching, he held it by a band of silk attached to the key. As the cloud passed over it, he beheld the fibres of the string

suddenly bristle up, and, holding his knuckle to the key, he received a strong electric spark. As soon as the string became wet, the supply of electricity was copious. He afterwards prepared an insulated iron rod, to draw the lightning into his house, and by means of real lightning he performed all the experiments usually executed by common electrical machines. In this discovery the French had the precedence in point of time, but they had only followed in the path which Franklin explicitly pointed out.

Upon the public announcement of this discovery, the experiment was repeated in various parts of Europe, and the consequences were such as occasioned alarm and terror. Many persons who incautiously attempted to bring down the ethereal fire suffered much by violent shocks, while they incurred the most imminent danger. In one instance, a fatal catastrophe ensued. On the 6th of August, 1753, Professor Richman, of St. Petersburg, was making experiments on lightning drawn into his own room. He had provided himself with an instrument for measuring the quantity of electricity communicated to his apparatus; and as he stood with his head inclined to it, his attendant observed a globe of blue fire, as large as his fist, jump from the instrument, which was about a foot distant, toward his head. Richman was instantly killed, and the attendant was much hurt. The latter could give no particular account of the way in which he was affected; for at the time the professor was struck, he stated that there arose a sort of steam or vapor which entirely benumbed him, and made him sink down to the ground, so that he did not even hear the clap of thunder, which was very loud. The

globe of fire was attended with an explosion like that of a pistol; the electrical instrument was broken to pieces, and the fragments were thrown about the room. A red spot appeared on the forehead of the dead body, and a blue spot on the foot, from which the shoe had been torn; whence it was inferred that the lightning had entered at the head, and passed off at the foot. On the back of the attendant's coat appeared long, narrow streaks, as if red-hot wires had burnt off the nap.

Common electrical experiments, however, are perfectly safe, provided an ordinary degree of caution is observed. A great multitude of devices may be resorted to for showing the singular properties of electricity. The *artificial aurora borealis* may be exhibited in the following manner. Take a glass phial, in shape and size like a Florence flask, with a stopcock fitted to it. Place it under the receiver of an air-pump, exhaust the air, and close the phial. Rub the glass in the usual manner for exciting electrics, and it will immediately appear luminous within, and a flashing light will be observed, forming a striking miniature resemblance of the northern lights. The phial may be made luminous by holding it in the hand, with one end presented to the prime conductor of an electrical machine; the strong, flashing light which then appears will remain for some time after it is withdrawn; and even after several hours have elapsed, on grasping the phial with the hand, strong flashes of light will reappear.

If a bundle of hair or feathers be hung upon the prime conductor, the moment they are electrified, by

working the machine, they begin to repel and fly from one another, and will not again collapse until the electricity is taken off. A fanciful mode of showing this experiment consists in making the form of a human head, with hair on it; and, upon placing this image upon the electrified conductor, the hair immediately shoots up "like quills upon the fretful porcupine." If two persons — one standing on an insulated stool, and communicating with the prime conductor, while the other stands upon the floor — hold in their hands plates of metal in such a manner that the flat sides shall be opposite to each other at the distance of about two inches, — on strongly electrifying the insulated person, dense and frequent flashes will be observed between the plates, forming a kind of artificial lightning.

Insulate two bodies, and charge one of them *plus*, and the other *minus*; then suspend between them, by a silken string, an artificial spider, of which the body may be cork, and the legs the fibres of feathers; the spider will move from the one to the other, till their charge is equalized. Place a cap or covering of metal upon the two extremities of a glass tube, four or five inches long, and enclose in the tube some sawdust or pith-balls; then charge one of the plates *plus*, and the other *minus*; when, as glass is a non-conductor, the equilibrium can be restored only by the sawdust or balls, which will accordingly jump up and down, till the charge of each plate is the same. To illuminate water, connect one end of a chain with the outside of a charged jar, and let the other end lie upon the table; place the end of another piece of chain at the distance of about a quarter of an inch from the former; then

set a decanter of water upon these separated ends, and, on making the discharge, the water will be illuminated.

Every one knows the use of lightning-rods, which, by means of their sharp points at the top, draw off gradually the electric matter in the clouds, and convey it to the earth, where it is dissipated. Personal security during a thunder-storm forms another important object of consideration. Franklin advises persons apprehensive of lightning to sit in the middle of the room, not near a metal chandelier, or any other conductor, and to lay their feet in a chair. A precaution of this kind is the easiest that can be observed, and insures a high degree of safety. It will be still safer to lay two or three beds or mattresses in the middle of the room, and, folding them double, to place the chairs upon them. A hammock, suspended by silken cords, would be an improvement even upon this apparatus. The floor should be dry, or the lightning, if it strikes the house, will fly all over the room. As the walls and floors of houses are usually dry, and therefore non-conductors, the lightning is prevented from spreading, and seizes with the more avidity the slightest articles of metal in its way. A person has been known to be struck dead by having his head near a bell-wire during a thunder-storm. Even the electricity conducted by the gilding of a picture-frame would be highly dangerous. Dr. Priestley observes, that the safest place is the cellar, and especially the middle of it; for when a person is lower than the surface of the earth, the lightning must strike the earth before it can reach him; it is therefore most probable that it will become imme-

diately diffused, and not enter the cellar, especially if it be dry.

The best situation for a person who happens to be in the fields during a thunder-storm is within a short distance of a tree, but not immediately under it, as the lightning generally strikes first the highest and best conductors. The frequency with which barns in the country are struck by lightning has been the subject of much remark; it seems not unlikely that, from their contents of fresh hay, grain, and other matters, they are constantly sending upward a column of vapor, which may serve as a conductor to bring down the electric fluid. It would appear, therefore, that they are unsafe places of shelter when there is lightning in the atmosphere.

GALVANISM.

THIS science is a branch of natural philosophy which has originated within a few years, and derives its name from Galvani, a professor of anatomy at Bologna, in Italy. He had the good fortune to make some observations on the electricity of the muscles of frogs, which appeared to him to depend on a new power in the animal body; and although it is now generally admitted that he drew an erroneous inference from his observations, yet they led to a train of experiments which have associated his name with some of the most brilliant discoveries of modern science. To this supposed new power he gave the name of *animal electricity*, conceiving it to depend upon something inherent in the animal body itself; but we now regard these effects as produced by minute quantities of the electric fluid set at liberty by a certain agency of substances upon each other.

The original discovery took place by accident. The wife of Galvani, being in ill health, employed, as a restorative, frog-soup, according to the custom in that country. A number of these animals, skinned for the purpose of cooking, chanced to lie near an electrical machine. While the machine was in action, an attendant happened to touch, with the point of a scalpel, the thigh of one of the frogs, when it was observed that the muscles of the limb were instantly thrown into

strong convulsions. This experiment was performed in the absence of the professor, but it was noticed by his wife, who communicated it to her husband. He repeated the experiment, varied it in different ways, and perceived that the convulsions took place only when a spark was drawn from the prime conductor, while the nerve of the thigh was at the same time touched with a substance which was a conductor of electricity. When a frog was so placed as to form a part of an electric circuit, it was found that an extremely minute quantity of electricity produced convulsions in the muscles: if the hind legs were dissected from the body,—the connection being kept up by the crural nerves only,—and the electric fluid was passed through it in this state, a still more minute quantity produced a visible effect, so that a frog prepared in this manner was capable of exhibiting very decisive marks of electricity, when none could be detected by an electrometer.

After employing the electric fluid as disengaged from the common machine, he next tried the atmospherical electricity; and it was in this experiment that he was first led to observe the effects of galvanism, properly so called. Having suspended a number of frogs by metallic hooks to an iron railing, he found that their limbs were frequently thrown into convulsions when it did not appear that there was any electricity in the atmosphere. Having duly considered this phenomenon, he discovered that it did not originate from an extraneous electricity, but that it depended upon the position of the animal with respect to certain metallic bodies.

The first stage or epoch in the history of galvanism must be considered that in which it was observed that excited electricity produced muscular contractions in dead animals; the second is that in which it was observed that different metallic bodies, by mere contact, produced the same kind of contractions; the third and most remarkable one commences with Volta's admirable discovery of the means of accumulating the galvanic influence. This invention, which justly confers so much celebrity on its author, is, in galvanism, analogous to that of the Leyden phial in common electricity; and became, like the phial, the precursor of the most brilliant discoveries. We can form, as yet, but a very imperfect judgment of the importance of the consequences to which it will lead. It is called the *Voltaic pile*, and is made by combining the effects of a number of plates of different metals, by which means a galvanic battery, capable of giving a shock, is produced. As silver and zinc had been found—when a single plate of each was employed—to have the greatest effect in producing muscular contractions, these metals were selected by Volta for his battery. The silver plates generally consisted of coins, and the plates of zinc were of the same size. The like size and number of pieces of cloth, pasteboard, or leather, steeped in salt water, were also provided. These substances were piled upon each other alternately, and the whole pile was supported by some non-conducting substance.

The Voltaic pile is now but little used in its original shape, having been superseded by galvanic batteries of a more convenient form, particularly when a great accumulation of galvanism is required. The pile or

battery is found to unite the effects of as many pair of plates as it contains. A pile of 50 pair will give a pretty smart shock, similar to that from an electrical machine when touched by the two hands simultaneously at the two extremities; but little or no shock is perceived unless the hands are moistened. The effects are also increased when a larger surface of the body is exposed to action. Thus, if the communication is made by touching with the tips of the fingers only, the effect is not perceived beyond the joints of the knuckles; but if a spoon or other metallic substance be grasped in moistened hands, the shock is felt up to the shoulders. If the communication be made between any part of the face, particularly near the eyes, and another part of the body, a vivid flash of light, corresponding with the shock, is perceived. This phenomenon may be more faintly observed by putting a piece of silver between the upper lip and the gum, and laying a piece of zinc at the same time on the tongue; upon bringing the two metals into contact, a faint flash of light generally appears. It is singular that this light is equally vivid in broad day as in the dark, and whether the eyes be shut or open.

Frogs have been found the most convenient subjects for galvanic operations. Galvani prepared these animals by skinning their legs when recently dead, and having them attached to a small part of the spine, but separated from the rest of the body. Any other limb may be prepared in a similar manner, by depriving it of its integuments, and laying partly bare the nerve which belongs to it. The strongest contractions are produced when the galvanic electricity is made to

pass through the nerve to the muscles. Frogs which have been galvanized quickly become putrid. Perhaps most persons who try galvanic experiments merely for the purpose of amusement would choose to dispense with the operation of decapitating and skinning frogs. We may therefore observe that an ample proof of the power of galvanism over the dead muscle may be obtained by galvanizing any animal killed for the kitchen. It will be necessary only to point the wires from the battery, and to penetrate the skin with them, at the two parts between which a communication is intended to be made.

Those animals only which possess distinct limbs and muscles can be convulsed by galvanism; yet reptiles may be affected by it. Thus, if a leech or worm be laid upon a plate of zinc, and surrounded at a little distance by half dollars, every time the animal touches one of the pieces of silver, it will be observed to shrink back. The medical uses of galvanism cannot yet be fully estimated. In some cases, it has proved beneficial; in others, it has had no effect whatever; and in others still, an unfavorable effect has been ascribed to it. The cases in which it is in general most proper to try it, are those in which common electricity has failed. In instances of numbness, palsy, and suffocation, it has proved highly advantageous.

The electricity of the torpedo, and the electrical eel, has a considerable resemblance to galvanism; it gives a sensible shock, but has little power of any other sort, and might be well imitated by a vast number of minute plates put in action by a fluid feeble in its power of oxidation.

The history of science affords many examples of observations which have remained isolated and useless for ages, and which, though often denied and discredited, have, by the progress of discovery, grown into importance, and become parts of a beautiful system — contributing, at the same time, essentially to the early maturity of some departments of knowledge. Hence those who have accurately detailed a single new phenomenon, which appeared to have no connection with any thing useful or any thing known, have, in fact, often been performing a work which should give celebrity to their names, by the direction which it has given to inquiry, and the light it has afforded to subsequent researches. In galvanism, several instances of the kind have occurred, and some of them are so curious as to deserve mention.

A long time prior to the establishment of galvanism as a science, it had been observed that, if two different metals were placed in contact under water, they were subject to a rapid oxidation, though the water had no perceptible action upon them when they were apart. It had also been observed that ancient inscriptions made of mixed metals were totally defaced, while those made of pure metals, equally old, were in excellent preservation. When metals have been soldered by means of other metals, they were found to contract a tarnish about the parts where they were joined; and the copper sheathing of ships, when fastened with iron nails, soon corrodes where the different metals are in contact. It had been generally affirmed that porter drunk out of a pewter vessel had a taste different from that drunk out of glass or earthenware, &c. It is now

evident that, in all these cases, the effects were produced by galvanic action.

Several persons may receive the galvanic shock together, by joining hands, in the same manner as in receiving the shock from a Leyden jar. Their hands should be well moistened; but, unlike electricity, the strength of the shock diminishes as it proceeds, in consequence of which, the last person feels it much less violently than the first. After receiving the shock, a slight numbness of the part exposed to it remains for some time. The shock may be also conveniently given by placing the hands or feet in salt water, and bringing wires from each end of the battery into the liquid. If any other part of the body is intended to be operated upon, a sponge moistened with salt water, and fastened to a metal plate connected with one end of the battery, may be applied to the part, and the hand or foot put into a vessel of the same liquid, connected by a wire with the other end of the battery.

The decomposition of water by galvanism is easily effected. The simplest mode of performing this experiment is, to bring the wires coming from each end of the battery into a vessel of water. A profusion of bubbles of gas will appear to be given out from each wire as far as it is immersed in the liquid. The closer the wires are brought together, so as not to touch, the more rapidly decomposition goes on. The gas produced from the wire coming from the zinc end of the battery, if the wire be of gold or platina, will be oxygen; but if the wire be of any metal more oxidable, no gas will appear, but the wire will be oxidated. The gas furnished by the wire from the copper end of the

battery, of whatever metal the wire may be, is of pure hydrogen. Both the gases are produced by the decomposition of the water.

Batteries containing 6000 or 8000 square inches of zinc and copper surface, furnish the means of performing a variety of experiments in which light and heat are abundantly extricated. Such a battery, in its highest state of energy, will make red-hot, and even fuse, a considerable length of fine steel wire, when it forms part of the circuit in making the connection between the two ends of the battery. Attach to the end of each wire of the battery a small piece of charcoal: on completing the circuit, by bringing the two pieces of charcoal into contact, a light, the most vivid that the eye can behold, immediately appears. The charcoal should be prepared for the purpose by burning some very hard, close-grained wood in a closed vessel. The foils, or thin leaves, of gold, silver, tin, and other metals, may be consumed by the help of mercury. Let the conducting wire from one end of the battery terminate in the mercury, in a small iron dish; to the other conducting wire attach the foil or wire to be deflagrated, and, upon touching the mercury with the latter, the effect will follow. The light afforded by the combustion of different metals is of different colors. Copper or brass leaf, commonly called *Dutch gold*, burns with a green light; silver with a pale blue light; gold with a yellow light; and all with a slight crackling. The galvanic discharge fires gunpowder, hydrogen gas, oils, alcohol, &c.

One of the most brilliant discoveries in modern chemistry was effected by the application of galvanism.

This was the decomposition of the fixed alkalies, by Sir Humphry Davy. These alkalies — namely, soda and potass — were supposed to be simple bodies; but Davy discovered them to be metallic oxides. A small piece of one of these oxides being laid upon a piece of platina connected with one end of a powerful battery, and another piece of platina, connected with the other end of the battery, being brought into contact with it, a portion of black matter is soon formed, in which are found imbedded small metallic globules. These globules are the base of the alkali, which has been deprived of its oxygen by the action of the battery. Experiments made by Davy, and other chemists, also showed that many other substances before supposed to be simple — as lime, barytes, strontites, magnesia, zircon, &c. — were capable of analysis; and though silex, alumina, and others, offered great resistance to the application of galvanism, in the majority of cases the analysis was successful. In giving a theory of galvanism, we are struck with a primary question: How does galvanism differ from common electricity? This query may refer both to the nature of the phenomena themselves, and to the means employed for their production. It is in some cases difficult to draw the exact line of distinction between the two principles, and many persons doubt whether any precise distinction actually exists. For, as it is conceived that they both depend upon the same agent, having merely experienced some modification in its nature, or mode of action, we must conclude that there may be some intermediate or indeterminate state which might be referred to the one or the other with almost equal propriety.

The electricity produced by the galvanic battery is of the same nature as that given by the common electrical machine; the only difference being that the mode of producing galvanism is continuous; that is, when in any way discharged, it is immediately reproduced by the oxidation of the zinc; and hence many galvanic phenomena have been successfully imitated by a series of sparks of ordinary electricity.

MAGNETISM.

THE word MAGNETISM, in its original and particular acceptation, is employed to denote that invisible force with which certain ores of iron, called in Greek *magnes*, attract pieces of iron to themselves. This property is found naturally in all the ores of oxidulated iron; but when the laws of its action are known, we may excite it artificially in metallic iron or steel by a particular process. Of the nature of the principle which produces the phenomena of magnetism, we are entirely ignorant.

Of magnets there are two kinds — the natural and the artificial. The *natural* magnet, or loadstone, is an ore of iron, hard enough to strike fire with steel: its color is dull, generally dark gray, brown, or nearly black. The power of magnetic attraction may be communicated to iron in any state; and a bar of iron possessing it in any considerable degree is called an *artificial* magnet. Magnetism is an accidental property of iron, and the metal may either possess or be deprived of it without losing any of its essential characteristics as a metal. Magnetic attraction was, till lately, supposed to be exerted by ferruginous bodies alone on other ferruginous bodies, and hence the use of the magnet was resorted to as a sure means of detecting the presence

of iron; but modern investigations have shown that nickel is also susceptible of it; cobalt is likewise supposed to be magnetic.

A magnet suspended by a thread, or placed in any situation that leaves it at liberty to move with freedom, turns one end toward the north. The two ends of a magnet are, therefore, called its *poles;* they are not reversible points, but the pole which is at any time observed to point toward the north will always point in the same direction, or nearly so. The attractive properties of the magnet have been known from time immemorial, and its polarity was known in Europe as early as the middle of the 12th century. Of course there is no ground for the current belief that the mariner's compass was invented by Gioja of Amalfi, in the 14th century. It is pretty satisfactorily ascertained that the Chinese had compasses long before the Christian era; but although the use of them on land was common, they do not appear to have been applied to the purposes of navigation till the 3d or 4th century, when they are distinctly mentioned in the Chinese histories. That the Europeans derived the compass from the East, is evident from the fact, that it was known on the coast of Syria before it appeared in Europe, whither it was undoubtedly carried by the crusaders. The first distinct mention of it in Europe is in a satire, written by Guyot de Provins, about the year 1190. The French, in consequence, lay claim to the discovery of the compass; and this notion has been strengthened by the circumstance of the north pole being marked on the card with a *fleur de lis*; but this figure is supposed to be only an ornamented cross.

The most simple method of exhibiting the power and distribution of magnetism, in a piece of natural loadstone, is to roll it in the filings of iron: on taking it out, it will be perceived that the filings have accumulated at the two ends of the loadstone, leaving the middle comparatively bare. If we examine these crests of filings attached to the poles of the loadstone, we shall observe that they radiate by adhering end to end to one another. This phenomenon is particularly deserving of attention, as it informs us that iron, placed in contact with a loadstone, becomes itself magnetic, in the same manner that an insulated body becomes electric when held in the presence of another body that is electrified.

Magnetism may be communicated to a bar of steel in a more prompt and energetic manner by two loadstones than by one, by placing its two extremities in contact, at the same time, with the contrary poles of the loadstones. The same loadstone may thus successively render magnetic any number of bars, without losing any portion of its original virtue; from which it is evident that it communicates actually nothing to the bars, but only develops, by its influence, some hidden principle. In the same manner, a stick of sealing-wax, when rubbed, loses nothing of its electricity by the decomposition which its influence effects at a distance in the natural electricities of other bodies.

When we hold one of the poles of a loadstone at a distance from a magnetic needle, suspended horizontally by its centre, the two poles of the loadstone act at once upon the needle, but the action of the nearest pole is always the strongest. The needle then turns toward

the loadstone the pole which is attracted, and keeps at a distance the one which is repelled. If, after it has taken a position of equilibrium, we turn it ever so little from its place, it will return to it by a series of oscillations, in the same manner as a pendulum, pushed from the perpendicular line, will return to it by the influence of gravity. A motion absolutely similar to this is observed in magnetic needles, freely suspended, when they are pushed ever so little out of the magnetic meridian. From this circumstance, therefore, as well as from the constant direction which it gives them, it appears that the terrestrial globe acts upon them exactly like a true magnet. Whether this faculty is owing to the mines of iron and magnetic substances which it contains, or whether it depends upon some other cause, we are yet ignorant.

The directive property of the magnet is one of the most important discoveries ever made by man. It gives to navigators an infallible guide to point their course across the trackless ocean, in the midst of the darkest nights, and when fogs or tempests have entirely obscured the heavens: a magnetic needle, balanced upon a pivot, points out to them the fixed direction in which they ought to keep, and this valuable indication conducts them as accurately as even the observation of the stars. Previous to this invention, so useful and simple, the seaman could not venture to a distance from the coast. The discovery of the compass has given him the means of launching into the farthest depths of the ocean, and of seeking regions unknown to the most powerful and enlightened nations of antiquity.

The magnetic needle does not, in general, point

exactly north and south; and this deviation, which is different in different parts of the globe, and is even different according to the hour of the day, was first observed by Columbus on his voyage of discovery to America, in 1492. The phenomenon caused great alarm at the time, for it was feared that the only guide which the mariner possessed, to conduct him across the trackless waste, was about to fail him. Succeeding observations, however, have shown that this irregularity is subject to certain laws, and that the earth has a magnetic pole, which does not exactly correspond to the rotatory pole. The aberration from the true north and south line is called the *variation of the compass.* It occurs at different hours of every day, and at different seasons of the year, but it is not exactly periodical. It is also very observable at the time of the appearance of the northern lights. The greatest variation from the north toward the west takes place about 2 o'clock in the afternoon, and the nearest approach of the needle to the pole is about 8 in the morning. The needle has an annual progress, between January and March, toward the west; between March and May it returns toward the north; in June it is stationary; in July it varies again to the west; in August, September, and October, it returns again toward the pole, and during the remainder of the year it varies westerly. Before volcanic eruptions and earthquakes, the needle is often subject to extraordinary agitations. Before 1657, the variation was easterly; during that year, the needle pointed due north; and the variation to the west has constantly increased ever since.

The magnetic needle is also subject to an influence

called the *dip*. When a bar of iron unmagnetized is balanced in an exact horizontal position, and the magnetism is afterwards applied, the north pole of the magnet will *dip*, or point, below the horizon. This movement varies in different latitudes; in the southern hemisphere, it is the south pole of the magnet which dips; at the equator there is hardly any dip.

Magnetism is transmitted through all bodies; and, apparently, through those which are the most solid with as much ease as through the most porous. In moving a magnet to and fro, under a slice of cork or a plate of gold, the effect upon bits of iron lying upon these substances appears to be the same; and no difference is observed whether magnetical experiments are tried *in vacuo*, or in the open air. But there are other causes which render magnetism one of the most mutable of powers. It is weakened by an increase of temperature; and a white heat almost entirely eradicates it.

Magnetic repulsion takes place only between poles of the same name. Thus a north pole always repels a north pole, and a south pole repels a south pole: yet it is observed that, when the north pole of a weak magnet is presented to the north pole of a powerful one, an attraction often appears. But when this occurs, it is found that the poles of the weaker magnet have in reality been reversed. The middle part of a magnet, exactly between the extremities of the poles, possesses no power either of attraction or repulsion; but if the magnet be divided in the middle, each half will become a distinct magnet; and those parts which were the north and south poles of the single original magnet

will still retain their character. The position in which a magnet is kept, and the manner in which it is loaded, have an effect upon its power. If it be constantly kept with its pole to the north, and be loaded with a weight which is gradually increased, it acquires additional magnetism. But in proportion as its position deviates from the pole, and if at the same time it is kept with little or no weight upon it, the magnetical power is soon materially impaired.

In the northern hemisphere, the north pole of a magnet is considered the most powerful; in the southern, the south pole predominates. But, in order to render a magnet capable of raising the greatest weight possible, an artifice is adopted to render both poles active in lifting the same load. This is done, in what is called the *horse-shoe* magnet, by bending the bar into a horseshoe till the two poles nearly touch. By combining many bars into one magnet, an enormous power may be obtained. Magnets of this sort are used by artisans to *touch*, or magnetize, compass-needles. A magnet employed in the communication of magnetism rather gains than loses in strength, but it cannot impart a greater degree of power than its own. Every kind of violent percussion, or whatever disturbs or deranges the disposition of the particles of a magnet, weakens its power. A strong magnet has been entirely deprived of its magnetism by several smart strokes of a hammer. The effect of the hammer is in some measure correspondent to what takes place in the tube-magnet. A glass tube filled with iron filings may be magnetized like a steel bar, and become a perfect magnet; but when the situation of the filings among themselves is

altered by shaking the tube, the magnetism disappears.

In some instances, magnetism may be obtained without the agency of a magnet. Thus, if a bar of iron, three or four feet long, be held in a vertical position, or, what is more proper, in the direction of the dipping-needle, it will immediately show signs of magnetism, by attracting light pieces of iron. The lower end of the bar will be the north pole; but if the bar be inverted, the pole will change likewise. On the south side of the equator, the lower extremity is always the south pole. To succeed in this experiment, the iron should be soft. Bars of iron which have for a long time remained entirely or for the most part in a vertical position — as fire-irons, bars of windows, &c. — are generally found to be more or less magnetical. If a long piece of iron be made red-hot, and then left to cool in the direction of the dipping-needle, it becomes magnetical. It has been observed that to strike a magnet with a hammer may deprive it of its magnetism: on the other hand, it is found that if a magnetical bar be struck with a hammer, or rubbed with a file, while held in the position of the dipping-needle, it will acquire magnetism. An electrical shock produces the same effect, and lightning often renders bars of iron magnetic; but both lightning and the electric shock will destroy the power of magnets already formed.

A circular piece of iron, like the verge of a watch, may have a north or south pole; and when the verge of a watch happens to acquire magnetism, its constant tendency to one direction has a material influence on the performance of the machine. A watch which

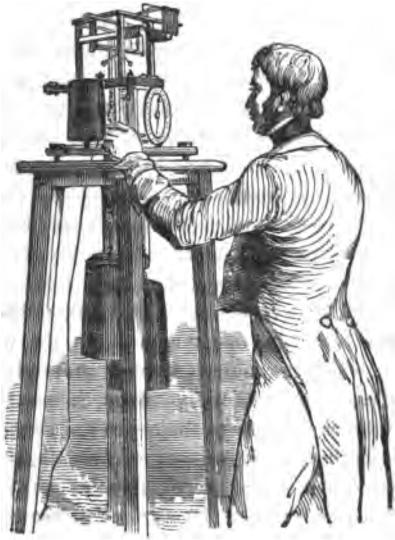
moved incorrectly with a steel verge, kept perfect time when a gold one was substituted, and the steel verge, on trial, was found to possess polarity. This fact is an important one to watch-makers, who sometimes are unable to discover the cause of the defective movement in a watch that appears to be in perfect order.

Many ingenious theories of magnetism have been broached by men of science; but the only proposition concerning it which seems placed beyond the reach of doubt is, that the earth itself acts as a great magnet; and if this be evident, it will scarcely be denied that all other magnets derive their power and properties from its effects. That the earth is a magnet, admits of strong collateral proofs. It may be inferred from the vast quantities of ferruginous bodies contained in it, which are often dug up in a magnetic state, and from the magnetism which iron acquires by its position. Yet all this carries us but a very little distance towards a complete theory of magnetism; and the difficulties yet in our way are very serious. For example, it is found that the magnetical poles of the earth change their situation, and this singular circumstance has opened a wide field for speculation. It has been supposed that the earth contains a detached internal magnet, which has a motion different from that of the earth, though their axes coincide. This internal loadstone is supposed to be separated from the outer globe, or earth, by a fluid medium; and, to explain the constant variation of the needle westward, the advocates of this theory assume that its motion with respect to the earth is such, that its north pole revolves from east to west at the rate of one degree in five years, so as to make a com-

plete revolution in 1920 years. To explain the reason why the motion of the internal loadstone should be less than that of the earth, they suppose that the diurnal motion of the earth arose from an external impulse, which was thence communicated, with a slight diminution, internally.

But this theory has never given much satisfaction. The regularity of motion assigned to the internal loadstone leaves entirely unexplained the frequent variations actually observed; and the attempt that has been made to supply this deficiency by supposing that there are within the earth four magnetic poles, which are movable with respect to each other, only looks like a wild effort to secure a solution of the mystery, whatever may be sacrificed to obtain it. It seems much more rational to conclude that the magnetism of the earth arises from the magnetism of all the magnetic substances which it contains, whether intermixed with other bodies or not; that the magnetic poles of the earth may be considered as the centres of the polarities of all the particular aggregates of the magnetic substances; and that these principal poles must change their places, relatively to the surface of the earth, according as the particular aggregations of magnetic substances within the earth are, by various causes, altered so as to have their power diminished, increased, and moved to or from the principal poles. The agents adequate to the production of these effects may be heat and cold, volcanoes, earthquakes, electricity, chemical decomposition, and probably several others of which we have no knowledge.

ELECTRO-MAGNETISM.



The Electro-Magnetic Telegraph.

THIS science is of very recent date, and must be considered as yet in its infancy. It was for many years suspected that there existed a strong analogy, if not a complete identity, between the electric and magnetic fluids; and various attempts were made to establish such a relation on satisfactory principles. It was known, for instance, that lightning destroyed and

reversed the polarity of magnetized needles, and that it produced a magnetic power in pieces of steel. Now, lightning and electricity have long been known to be the same; consequently, electricity ought to produce similar effects to lightning on magnetic and simple steel bars; but the attempts which were made to discover a satisfactory proof of this action, by means of the electric apparatus, had little success; and all that was effected in this way amounted only to communicating the magnetic property to steel bars, but without enabling the experimenter to predict in what directions the poles would lie, — and therefore was little more than might be produced by a blow, by twisting, and various other means.

This method of tracing the analogy between the electric and magnetic fluids having failed, recourse was had to the galvanic battery, which was known to possess electrical properties. By means of this agent, gold needles were magnetized; but the relation between the two fluids still remained doubtful till Professor Oersted, of Copenhagen, instituted a series of experiments which led to the most successful results. These experiments are of too complicated a nature to admit of a detailed description here. The theory of electro-magnetism has not yet been settled, and we cannot make the principle of this science intelligible to the reader any further than by saying that electric currents are supposed to be revolving round the component particles of magnetized substances. When a magnetic needle is placed near a conducting wire in the plane of the magnetic meridian, and the wire is connected with a strong galvanic battery, the middle will turn round, placing itself at right angles to the

direction of the current. Now, as the transmission of electricity through a conducting substance is instantaneous, a wire or other conductor may have motion communicated to its whole length at the same moment, whatever that length may be; and it is stated that an electro-magnetic impulse may be transmitted at the rate of 180,000 miles in a second.

By the help of this power has been constructed that wonderful machine, the Electro-magnetic Telegraph, of which the most successful and striking example is that of Professor Morse. This telegraph extends from Washington to Baltimore, a distance of upwards of forty miles. It consists of a conductor of copper wire, extending the whole distance between the two cities, on the tops of posts 25 feet in height, and at regular distances of 225 feet. A galvanic battery at one end transmits an electro-magnetic shock instantaneously through the whole length of this conductor; and, by peculiar management in varying the shocks, the extremity of the conductor is made to mark dots and lines upon paper, by the combination of which, the letters of the alphabet, and figures, are signified. In this manner, questions are asked and answered in a moment between the two cities. By this wonderful machine, both space and time are annihilated, for it is obvious that no limit can be assigned to the extent of such a correspondence. The utility of this invention is obvious at first sight, and it is not improbable that a very few years will see a system of telegraphic communication uniting all the great towns in the American Union.

MATHEMATICS.

Mathematics constitute the science which has for its object the abstract relations of number and magnitude, and their application, through the medium of observed laws, to the useful purposes of life and the explanation of natural phenomena. From this description, it follows that mathematical science naturally divides itself into two principal branches. The one, resting solely on our intuitive perceptions of abstract truth, and demanding no assistance from experience and observation, and very little from the evidence of our senses, constitutes the *pure mathematics*, and comprehends all inquiries into the relations of magnitude in the abstract, and the properties of extension. The other, taking for granted the truth of general laws deduced by legitimate inference from observations sufficiently numerous, supplies the hidden links which connect the cause with its remote effect, and endeavors, from the extent of the one, to estimate the magnitude of the other. This branch is called *mixed mathematics*.

The science of pure mathematics enjoys the highest rank in human knowledge, its object lying among the most simple, the most distinct, and the best-defined of our notions, while its reasoning consists of successive

decisions of judgment, in each of which the objects to be compared are brought before the mind with such perfect clearness as to render mistake impossible. Analogy, or likeness, that grand source of human error, is excluded from a science in which absolute equality or inequality in respect of magnitude is the only point which ever comes in question; while the practice of mathematicians, in defining strictly every term, and adhering rigorously to their definition in its employment, cuts off every possibility of mistake, from inaccuracy of language; and their extreme caution in dwelling upon, and analyzing, each successive step of their reasoning, saves them from the danger of precipitancy. Mixed mathematics, on the contrary, participates in the uncertainty which must always attend upon whatever concerns human observation, however far it may be pushed — since every conclusion which rests ultimately on such a basis must be infected with all the errors to which human observations, however carefully made, and however often repeated, are liable.

The nature of this science may be illustrated by specifying the difference between a mathematical assertion, and an assertion of any other kind. If we say that two straight lines cannot completely enclose a space, we utter a mathematical assertion, which is abstractedly true, and the contrary to which would be an impossibility. If we say that an unsupported stone will fall to the ground, we state a fact, of which we are as certain, as far as we *actually rely upon it*, as of the mathematical assertion. But in the mathematical proposition, the idea of a contradiction to it is an absurdity which the mind instantly rejects; whereas, in the case

of the fall of the stone, whatever the fact may be, there is no difficulty in conceiving of an exception, or even of a permanent alteration of the law by which it is made to fall.

Mathematics may be considered either as an instrument to discipline the mind, or to assist us in the investigation of nature and the advancement of the arts. In the former point of view, their object is to strengthen the power of logical deduction by frequent examples; to give a view of the difference between reasoning on probable premises and on certain ones, by the construction of a body of results which in no case involve any of the uncertainty arising from the previous introduction of that which may be false; to form the habit of applying the attention closely to difficulties which can be conquered only by thought, and over which the victory is certain if the right means be used; to give caution in receiving that which, at first sight, appears good reasoning; and to instil a correct estimate of the powers of the mind, by pointing out the enormous extent of the consequences which may be developed out of a few of its most inherent notions, and its utter incapacity to imagine the boundaries of knowledge.

As instruments in the investigation of nature and the advancement of the arts, it is the object of the mathematical sciences to give correct habits of judgment, and ready means of expression, in matters involving degree and magnitude of all kinds; to teach the method of combining phenomena, and ascending from complicated forms of manifestation to the simple law which regulates them; to trace the necessary conse-

quences of any law assumed on suspicion, in order to compare those consequences with actual phenomena; to make all those investigations which are necessary for the calculation of results, to be used in practice — as in nautical astronomy, application of force and machinery, and the conduct of money transactions; — in a word, to find out truth in every matter in which nature is to be investigated, or her powers, and those of the human mind, are to be applied to the physical progress of the human race.

The mixed mathematics are primarily dependent on the extent and accuracy of our scrutiny into nature; after which, their further advancement is limited only by the degree of perfection to which the pure mathematics are carried; but a very perfect knowledge of the latter is requisite to a very moderate knowledge of the former. The laws of nature, indeed, are, for the most part, simple in themselves; but the circumstances under which they act produce a complication in their agencies which calls, at once, for the most powerful exertions of natural reason, and the most refined artifices of practised ingenuity, to develop. Combinations are perpetually presenting themselves, where the principles are satisfactorily known, the general laws placed beyond a doubt, the mode of applying mathematical investigation thoroughly understood — yet which, by the mere complication of the pure mathematical inquiries which they involve, defy the utmost powers of calculation. The restless activity of nature surrounds us with minute phenomena of this kind. The motions and equilibrium of fluids, their capillary attraction, the vibrations of the atmosphere and of solid bodies, — every

breath of wind that blows, and every mote that sparkles in the sunbeam,—supply us with instances in point. On a wider scale, the simple law of gravitation, modified by the consideration of three gravitating bodies in motion, produces a problem which has resisted every effort of ingenuity and industry, stimulated by the strongest motives which can rouse man to exertion.

That part of mathematics which treats of numbering, is called *arithmetic*; that part which concerns measuring, or figured extension, is called *geometry*;—these, with *algebra* and *fluxions*, which are conversant with multitude, magnitude, form, and motion, being the foundation of all the other parts of the science, constitute the pure mathematics. The science is also distinguished into *speculative* and *practical* mathematics; the former when it is concerned in discovering properties and relations, and the latter when applied to practice and real use concerning physical objects. The peculiar topics of investigation, in the four principal departments of pure mathematics, may be indicated by four words,—namely, arithmetic by *number*, geometry by *form*, algebra by *generality*, and fluxions by *motion*.

In mathematics are several general terms or principles, such as definitions, axioms, &c., which require explanation. A *definition* is the explication of any term or word in a science, showing the sense and meaning in which the term is employed: every definition ought to be clear, and expressed in words that are common and well understood. A *proposition* is something proposed to be demonstrated, or something required to be done, and is accordingly either a *the-*

orem or a *problem*. A theorem is a demonstrative proposition, in which some property is asserted, and the truth of it required to be proved: thus when it is said that the sum of the three angles of a triangle is equal to two right angles, that is a theorem, the truth of which is demonstrated by geometry. A set, or collection, of such theorems, constitutes a *theory*. A problem is a proposition or a question requiring something to be done, either to investigate some truth or property, or to perform some operation. A *limited* problem is that which has but one answer; an *unlimited* problem is that which has innumerable answers. A *determinate* problem is that which has a certain number of answers. *Solution* of a problem is the resolution, or answer given to it. A *numeral* or *numerical* solution is the answer, given in numbers; a *geometrical* solution is the answer given by the principles of geometry; and a *mechanical* solution is one which is gained by trials and experiments.

A *lemma* is a preparatory proposition, laid down in order to shorten the demonstration of the main proposition which follows it. A *corollary*, or *consectary*, is a consequence drawn immediately from some proposition or principle previously demonstrated. A *scholium* is a remark or observation made upon some foregoing proposition or premises. An *axiom*, or *maxim*, is a self-evident proposition, requiring no formal demonstration to prove its truth, but received and assented to as soon as mentioned; such as, The whole of any thing is greater than a part of it; or, The whole is equal to all its parts taken together, &c. A *postulate*, or *petition*, is something required to be done, which is

so easy and evident that no person will hesitate to allow it. An *hypothesis* is a supposition assumed to be true, in order to argue from, or to found upon it the reasoning and demonstration of some proposition. *Demonstration* is the collecting the several arguments and proofs, and laying them together in proper order, to show the truth of the proposition under consideration. A *direct*, *positive*, or *affirmative* demonstration is that which concludes with the direct and certain proof of the proposition in hand. An *indirect* or *negative* demonstration is that which shows a proposition to be true by proving that some absurdity would necessarily follow if the proposition were false. This is also sometimes called *reductio ad absurdum*, because it shows the absurdity and falsehood of all suppositions contrary to that contained in the proposition.

Method is the art of disposing a train of arguments in a proper order to investigate either the truth or falsity of a proposition, or to demonstrate it to others when it has been found out. This is either *analytical* or *synthetical*. Analysis, or the analytic method, is the art or mode of finding out the truth of a proposition by first supposing the thing to be done, and then reasoning back, step by step, till we arrive at some known truth. This is also called the method of *invention*, or *resolution*. *Synthesis*, or the synthetic method, is the searching out truth by first laying down some simple and easy principles, and then pursuing the consequences flowing from them, till we arrive at the conclusion. This is also called the method of *composition*, and is the reverse of the analytic method, as it proceeds from known principles to an

unknown conclusion, while the other goes in a retrograde order, from the thing sought, considered as if it were true, to some known principle or fact. Therefore, when any truth has been found out by the analytic method, it may be demonstrated by a process in the contrary order, or by synthesis.

The reader will require no general description of a science so well known as ARITHMETIC. But there is a department of it not very generally understood, — namely, *logarithms*, — the invention of which, like many other inventions, was the offspring of necessity. In the infancy of astronomy, before the use of accurate instruments, or the discovery of the refined mathematical theories to which they have led, the calculations were fewer and shorter than in modern times. As the science advanced, however, they became more laborious and irksome, so as to render some method of abridging them highly desirable. About the end of the sixteenth century, some ingenious contrivances were found, by which the labor of calculation might, in particular cases, be shortened. But the most effectual, and, indeed, the only adequate, remedy was the artifice of logarithms, which, from its great utility, has formed an epoch in the history of science. This admirable invention is due to John Napier, Baron of Merchiston, in Scotland.

The word *logarithms* signifies the *ratio of numbers*. Logarithms, in fact, are the numerical exponents of ratio, or a series of numbers in arithmetical progressions, as 0, 1, 2, 3, 4, answering to another series in geometrical progression, or as 1, 2, 4, 8, 16, &c. They facilitate troublesome calculations, in performing

multiplication by simple addition; and performing division by subtraction; and raising of powers in multiplying the logarithm by the index of the power; and extracting of roots in dividing the logarithm of the number by the index of the root; for logarithms are numbers so contrived and adapted to other numbers, that the sums and differences of the former shall correspond to, and show, the products and quotients of the latter.

ALGEBRA is the science of investigation by means of symbols. It is sometimes also called *analysis*, and is a general kind of arithmetic, or universal way of computation. In this science, quantities of all kinds are represented by the letters of the alphabet; and the operations to be performed by them — as addition, subtraction, &c. — are denoted by certain simple characters, instead of being expressed in words at length. These characters, unlike the numerals of arithmetic, being altogether arbitrary, are employed to denote not only known quantities, but also the quantities which are required, or unknown. In some cases, the known quantities are most conveniently expressed by the common numeral characters, as in arithmetic; but in others it is better to represent both the known and the unknown quantities by other symbols. The letters of the alphabet being usually selected for this purpose, it is common to employ those at the beginning, as a, b, c, d, &c., for known quantities, and those at the end, as, z, y, x, &c., for the unknown. There are also certain arbitrary signs used to express the relations of quantities to one another, and the operations which may be performed on them.

GEOMETRY is the science or doctrine of local extension — as of lines, surfaces, and solids, with that of ratios, &c. The word signifies, literally, *measuring of the earth*, as it was the necessity of measuring land which first gave occasion to study the principles and rules of this art, which has since been extended to numberless other speculations, — so that, together with arithmetic, geometry now constitutes the chief foundation of mathematical science: it is distinguished into *theoretical*, or *speculative*, and *practical*. Theoretical or speculative geometry treats of the various properties and relations in magnitudes, demonstrating theorems, &c. Practical geometry is that which applies those speculations and theorems to particular uses in the solution of problems, and in measurements in the ordinary concerns of life. Speculative geometry, again, may be divided into *elementary* and *sublime*. Elementary or common geometry is that which is employed in the consideration of right lines and plane surfaces, with the solids generated from them. Higher or sublime geometry is employed in the consideration of curve lines, conic sections, and the bodies formed from them. This part has been chiefly cultivated by the moderns, by help of the improved state of algebra, and the modern analysis, or *fluxions*. In the doctrine of *fluxions*, magnitudes or quantities of all kinds are considered as not made up of a number of small parts, but as generated by continued motion, by means of which they increase or decrease; as a line by the motion of a point; a surface by the motion of a line; and a solid by the motion of a surface. So, likewise, *time* may be considered as represented by a line, increasing

uniformly by the motion of a point; and quantities of all kinds whatever, which are capable of increase or decrease, may, in like manner, be represented by lines, surfaces, or solids, considered as generated by motion. Any quantity thus generated and variable is called a *fluent*, or a flowing quantity; and the rate or proportion according to which any flowing quantity increases, at any position or instant, is the fluxion of the said quantity at that position or instant.

TRIGONOMETRY, in its original sense, signified that part of mathematical science which treated of the admeasurement of triangles. These triangles were supposed to be described either upon a plane or upon the surface of a sphere; and hence the science was divided into *plane* trigonometry and *spherical* trigonometry. Like every other department of science, the objects of trigonometry became more extended as knowledge advanced and discovery accumulated; and this part of mathematics, which was at first confined to the solution of one general problem, — namely, certain sides and angles of a triangle being known, how to determine the others, — has now spread its uses over the whole domain of mathematical and physical science. In the wide range of modern analysis, there is scarcely a subject of investigation to which trigonometry has not imparted clearness and perspicuity, by the use of its language and its principles. The immediate object of this science is to institute a system of symbols, and to establish principles by which angular magnitude may be submitted to computation, and numerically connected with other species of magnitude; so that angles, and the quantities on which they depend, or which

depend on them, may have their mutual relations investigated by the same methods of computation that are applied to all other quantities.

Every triangle has six parts,— namely, three angles and three sides, and it is necessary that three of these parts be given, to find the other three. In spherical trigonometry, the three parts that are given may be of any kind — either all sides, or all angles, or part the one and part the other. But in plane trigonometry, it is necessary that one of the three parts, at least, be a side, since from three angles can only be found the proportions of the sides, but not the real quantities of them. Trigonometry is of the greatest use in the mathematical sciences, especially in astronomy, navigation, surveying, dialling, geography, &c. By help of it we ascertain the magnitude of the earth and the stars, their distances, motions, eclipses, &c.

The usefulness of the mathematical sciences may be illustrated by an example. Numberless experiments have shown us that all bodies near the earth's surface fall with an accelerated velocity, and that the spaces passed through are as the squares of the times they have been in falling. This, then, the mathematician considers as a necessary and essential quality of matter; and with this datum he proceeds to examine what will be the velocity of a body after any given time; in what manner it will have acquired any given velocity; what time is necessary for it to have generated a given space, &c. In all these investigations, his conclusions are as certain and indisputable as any of those which geometry deduces from self-evident truths and definitions. Again in optics,— having established it as

a principle of light, that it is transmitted in right lines while no obstacle is opposed to the passage of the rays; that it is reflected and refracted in a particular manner, — he considers the rays only as right lines, the surfaces of the bodies which cause their reflection and refraction only as geometrical planes, the form of which alone enters into his investigation; and from this point, all his inquiries are purely geometrical; his investigation is clear and perspicuous, and his deduction evident and satisfactory. To this class of mathematics belong *mechanics*, or the science of *equilibrium; hydro-dynamics*, in which the equilibrium and motion of fluids are considered; *astronomy*, which relates to the motion, masses, distances, and densities of the heavenly bodies; *optics*, or the theory and effects of light; and *acoustics*, or theory of sounds.

Such are the subjects that fall under the contemplation of the mathematician; and, as far as a knowledge of these may be considered beneficial to mankind, so far, at least, the utility of the science on which they depend must be admitted. It is not, however, the application of mathematics to subjects connected with common life, that constitutes their peculiar excellence; it is their operation on the mind, the vigor they impart to our intellectual faculties, and the discipline which they impose upon our wandering reason. "The mathematics," says Dr. Barrow, "effectually exercise, not vainly delude, nor vexatiously torment, studious minds with obscure subtilties; but plainly demonstrate every thing within their reach, draw certain conclusions, instruct by profitable rules, and unfold pleasant questions. These disciplines also inure and corroborate the mind

to a constant diligence in study; they wholly deliver us from a credulous simplicity, and most strongly fortify us against the vanity of skepticism; they effectually restrain us from a rash presumption, and easily incline us to a due assent, and perfectly subject us to the government of right reason. While the mind is abstracted and elevated from sensible matter, it distinctly views pure forms, conceives the beauty of ideas, and investigates the harmony of proportions; the manners themselves are sensibly corrected and improved; the affections composed and rectified; the fancy calmed and settled; and the understanding raised and excited to more divine contemplations."

Many will consider the above as the language of an enthusiast, for the science of mathematics is not without its detractors. It has been represented as a science which blunts all the tender feelings of our nature, and renders those who cultivate it vain, arrogant, and presumptuous; as destroying all relish for works of taste and imagination, hardening the heart against every truth but those of the demonstrative kind, and, consequently, as having a tendency to lead men to infidelity and atheism. Dr. Johnson seems to have been tinctured with these opinions. "It was the great praise of Socrates," he observes, "that he drew the wits of Greece, by his instruction and example, from the vain pursuits of natural philosophy to moral inquiries; and turned their thoughts, from stars and tides, and matter and motion, to the various modifications of virtue and the relations of life." He pursues this thought still further, and illustrates it by a story which he tells of one Gelidus, a mathematician, who was so absorbed in

his speculations, that, when his servants came to acquaint him that a house was on fire, and the whole neighborhood in danger of being burnt, he only replied, "that it was very likely, for it was the nature of fire to act in a circle." He even divests this philosopher of the common feelings of humanity, and makes him as insensible to the wants of his family as to the distresses of his neighbors. This, however, is but a specimen of Johnson's illiberal feelings towards the professors of a science for which he happened to possess no taste. A great and comprehensive genius excludes none of the sciences; they all contribute, by various means, to adorn and improve human life, and consequently are all deserving of esteem and patronage.

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METEOROLOGY.

METEOROLOGY may be defined as that department of physical science which treats of atmospherical phenomena. The word *meteor* has, in our language, been almost exclusively confined to those luminous bodies which are seen occasionally in the atmosphere, and whose appearance and motion have not yet been reduced to any definite law. In Greek, however, the word *meteora* was indiscriminately applied to all bodies, whether luminous or opaque, that appeared in the atmosphere; and the term *meteorology* is still used in the same, and even a more extended, signification. It denotes the investigation, not merely of those atmospheri-

cal phenomena that are of comparatively rare occurrence, and may be more properly denominated *meteors*, but of the various changes, also, that are observed to take place in the state of the atmosphere itself. But for this extended application of the word, the subject would be comparatively uninteresting, and could with little propriety be dignified with the appellation of a science.

To the first class of atmospherical phenomena belong those luminous bodies that occasionally appear in the sky, and have been denominated *meteors*, or *shooting stars*. These bodies appear to be of different magnitudes, and even of various forms, though this last circumstance may, perhaps, be the effect of optical deception. In general, they seem to be globular, continuing visible only for a few seconds, and moving with great velocity. Their course is, on some occasions, in a straight line, and on others, curvilinear, rendered more distinct by the tail, or luminous train, which they leave behind them; and before disappearing, they are sometimes separated into several smaller bodies, accompanied with an explosion resembling thunder, more or less loud in proportion to their magnitude and distance. These explosions are followed sometimes by a shower of solid bodies, of a stony or metallic substance, some of which appear luminous in their descent after the explosion, and have been taken up before they had time to cool. We have already alluded to the subject of these meteorites in another part of this volume.

Another meteoric appearance is known by the name of the *ignis fatuus*, *Jack-with-a-lantern*, and *Will-with-the-wisp*. It is generally seen in dark nights, over

boggy and marshy ground, but generally in motion, at the height of five or six feet, skipping from place to place, and frequently changing, both in magnitude and form. On some occasions, it is observed to be suddenly extinguished, and then to reappear at a distance from its former position. Those persons who have endeavored to examine it closely have found, that it moves away from them with a velocity proportioned to that with which they advance—a circumstance which has had no small influence on the fears of the ignorant and superstitious. Dr. Derham once saw an *ignis fatuus* in a boggy place, between two rocky hills, in a dark and calm night. He approached by degrees within two or three yards of it, and thereby had an opportunity of viewing it to the best advantage. It kept skipping about a dead thistle, till a slight motion of the air—occasioned, as he supposed, by his near approach—caused it to jump to another place; and as he advanced, it kept flying before him. He observed it to be a uniform body of light, and concluded it must consist of ignited vapor. These appearances are very common on the plains near Bologna, in Italy, where they sometimes flit before the traveller on the road, saving him the expense of a torch on dark nights. Sometimes they spread very wide, and then contract themselves; and sometimes they float like waves, and appear to drop sparks of fire. They are more frequent, in that quarter, when the ground is covered with snow than in the heat of summer, and shine more strongly in rainy than in dry weather.

A meteoric appearance of the same kind is sometimes met with, at sea, during gales of wind, and,

of course, has become connected with many superstitious notions of the sailors, who call it a *corpusant.* There are sometimes two together, and these are named Castor and Pollux. The following is a description of one given by the voyager Dampier: "After 4 o'clock the thunder and the rain abated, and then we saw a corpusant at our maintopmast head, on the very top of the truck of the spindle. This sight rejoiced our men exceedingly, for the height of the storm is commonly over when the corpusant is seen aloft; but when they are seen lying on the deck, it is generally accounted a bad sign. A corpusant is a certain small, glittering light; when it appears, as this did, on the very top of a mainmast, or at a yard-arm, it is like a star; but when it appears on the deck, it resembles a great glow-worm. The Spaniards have another name for it; though I take even this to be a Spanish or Portuguese name, and a corruption only of *corpus sanctum;* and I have been told that, when they see them, they presently go to prayers, and bless themselves for the happy sight. I have heard some ignorant seamen discoursing how they have seen them creep, or, as they say, travel about, in the scuppers, telling many dismal stories that happened at such times; but I did never see any one stir out of the place where it was first fixed, except upon deck, where every sea washeth it about. Neither did I ever see any, but when we have had hard rain as well as wind, and, therefore, do believe it is some jelly." The origin and nature of the remarkable lights above described have not yet been explained; more numerous and accurate observations than have been made are re-

quired, to furnish the basis of an accurate theory respecting them.

Besides these meteors, there are other luminous appearances occasionally observed in the atmosphere — namely, *haloes*, *parhelia*, or *mock-suns*, and *paraselenai*, or *mock-moons*. These are supposed to indicate certain approaching changes of the weather. The luminous circle which is sometimes seen around the heavenly bodies, but especially the sun and moon, and which has received the name of *halo*, or *corona*, has, from a very early period, been regarded as a certain prognostication of stormy weather, accompanied with rain or snow, according to the climate or season. It frequently happens that, in the outer edge or circumference of this circle, there is a part less distinctly defined than the rest, apparently owing to the contact of a denser cloud; and it has been remarked by shepherds, and others who have frequent opportunities of observing this phenomenon, that the storm generally comes from that point of the compass towards which this indistinct portion of the circle, or *opening*, as it is called, is directed. This phenomenon, as well as its modifications, the parhelion and the paraselene, is obviously connected with a change of weather only in so far as it indicates some peculiarity in the existing state of the atmosphere. The same remark applies to the rainbow, though this last is rather a concomitant, than a prognostic, of rain. It has been remarked, however, that a rainbow in the morning is frequently followed by showers, while one in the evening forebodes fair weather.

It has long been a received opinion that the phases

of the moon have a certain influence on the weather, and these have accordingly furnished various prognostications. It is quite conceivable, on philosophical principles, that the atmosphere may be differently affected, in the same way as the waters of the ocean are, by the different positions of the sun and moon relatively to the earth; and that the result, in certain cases, may be a tract of settled or tempestuous weather, according to circumstances. At the same time, the subject is still involved in great uncertainty, nor does there appear to be any foundation for the popular opinion that certain sorts of weather will follow the changing of the moon, according as it happens in the east, west, south, &c.

But the most fertile source of prognostics is to be found in the various and ever-changing appearance of the clouds. As the proximate cause of rain or snow, they have in all ages been regarded as affording the surest and most direct intimation of approaching changes; and there are few persons, perhaps, who are not conscious of having frequently looked, instinctively as it were, to the appearance of the clouds, in order to form some opinion or conjecture respecting the future state of the weather. At the same time, there are few subjects on which there exist so great a diversity and vagueness of opinion. Indications drawn from the appearances of the clouds themselves are exceedingly indistinct, unless when accompanied with other circumstances, which render them more definite, — such as the color of the sky at sunrise or sunset, the settling of clouds on the summit of hills, the appearance of mist or fog at particular periods of the moon's age, &c. And though there are, no doubt, certain modifi-

cations of the forms of clouds, which nine, perhaps, out of ten, among *weather-wise* persons, would without hesitation pronounce to be indications of rain or snow, yet, if they were required to assign a specific reason for their opinion, scarcely two of them would be found to agree.

The following passage from Virgil's Georgics will show what prognostics of weather were regarded by the Romans in his day: —

Observe the daily circle of the sun,
And the short year of each revolving moon;
By them thou shalt foresee the following day,
Nor shall a starry night thy hopes betray.
When first the moon appears, if then she shrouds
Her silver crescent, tipped with sable clouds,
Conclude she bodes a tempest on the main,
And brews for fields impetuous floods of rain:
Or if her face with fiery flushing glow,
Expect the rattling winds aloft to blow.
But, four nights old — for that's the surest sign —
With sharpened horns if then she glorious shine,
Next day, nor only that, but all the moon,
Till her revolving race be wholly run,
Are void of tempests both by land and sea,
And sailors in the port their promised vows shall pay.
Above the rest, the sun, who never lies,
Foretells the change of weather, in the skies.
For, if he rise unwilling to his race,
Clouds on his brow, and spots upon his face,
Or if through mists he shoot his sullen beams,
Frugal of light, in loose and straggling streams,
Suspect a drizzling day, with southern rain,
Fatal to fruit, and flocks, and promised grain:
Or if Aurora, with half-opened eyes,
And a pale, sickly cheek, salute the skies,

How shall the vine, with tender leaves, defend
Her teeming clusters, when the storms descend?
When ridgy roofs, and tiles, can scarce avail
To bar the ruin of the rattling hail?
But more than all the setting sun survey,
When down the steep of heaven he drives the day.
For oft we find him finishing his race,
With various colors erring on his face.
If fiery red his glowing globe descends,
High winds and furious tempests he portends;
But if his cheeks are swollen with livid blue,
He bodes wet weather by his watery hue.
If dusky spots are varied on his brow,
And, streaked with red, a troubled color show,
That sullen mixture shall at once declare
Winds, rains, and storms, and elemental war.
But if with purple ray he brings the light,
And a pure heaven resigns to quiet night,
No rising winds or falling storms are nigh,
But northern breezes through the forest fly,
And drive the rack, and purge the ruffled sky.
Th' unerring sun by certain signs declares
What the late even or early morn prepares;
And when the south projects a stormy day,
And when the clearing north will puff the clouds away.

There is another class of prognostics — namely, those which are derived from phenomena observed on the surface of the earth, or, at least, in the lower regions of the atmosphere. These are of various kinds — such as the expansion and contraction of flowers; the motions and cries of certain animals; painful sensations in the human body, &c.; and though many of these are no doubt fanciful, yet others appear well entitled to the attention of meteorologists. Some of them, indeed, especially such as are drawn from the economy of plants,

admit of a philosophical and satisfactory explanation, as every one must know who is acquainted with physiological botany. It is probably owing to some atmospherical influence, of a similar kind, on the animal system, that the peculiar cries and motions of some beasts, and certain sensations in the human body, are found to indicate changes in the weather; though it may be difficult, or, in the present state of science, even impossible, to explain that influence. Thus it has been long observed, and very generally believed, that rain may be expected when swallows are seen dipping their wings in the water over which they are flying; when the crow cries more than usual; when water-fowl are more than usually clamorous and active; when dogs and cats are dull and sleepy; when the croaking of frogs is loud and general; when worms are seen in great numbers on the surface of the earth; when pigs run up and down with evident signs of uneasiness, which has given rise to the proverbial saying about "the pig that sees the wind." In the United States, we have various animals who announce changes of weather by their cries. A little reptile called the tree-toad, or tree-frog, is very clamorous before a shower; and the American quail, whose note sounds remarkably like the words *more wet*, gives the same warning.

That a change in the atmosphere, not perceptible by any appearance in the heavens, may yet affect the sensations of the human body as well as those of animals, is evident from the notorious fact that persons subject to rheumatism, and similar diseases, or who have accidentally suffered any injury in their limbs, generally feel more acute pain in the part affected before a

change of weather than at any other time; and there are instances where these pains are most severe before or during a sudden fall of the barometer. This coincidence points to something like an explanation of the phenomenon; but the subject has not yet been properly investigated.

The different parts of the surface of the globe are unequally exposed to the impression of the solar rays, and the intensity of this action depends on the latitude of the place, on the changes which take place during the day and the night, &c. Between this variable condition of the surface, and that of the temperature of the atmosphere, some relation must exist, which a well-devised theory must ultimately unfold. The heat existing from day to day in that portion of the atmosphere which is next the earth, is at no time the simple product of the direct action of the solar rays on that portion; and the accumulation of heat near the surface is evidently due to the stopping of the rays at that surface, to their multiplied reflections and refractions, in consequence of which they are, as it were, absorbed and fixed for a time in the soil and in the incumbent atmosphere. By this process, the earth, when in a cold state, at the end of winter, becomes gradually heated to a certain depth as the warm season advances; and on the other hand, as the sun declines in autumn, the heated soil acts as a warm body on the atmosphere, and gives out again the heat it had received, and, as it were, stored up. Similar vicissitudes during the day and the night, according as the sun's action is exercised or withdrawn from the terrestrial surface, contribute, in their part, to that unceasing variety which characterizes all

the conditions of the great body of air surrounding it. It appears, from experiments, that, were the earth's surface at a mean temperature, and the solar rays suddenly intercepted, it would require about thirty days to cool it down seven degrees, and about the same time to heat it to its former temperature on their return.

Our knowledge, however, of the actual condition of the earth's internal temperature, must be derived from observations made below its surface. It has been ascertained that, at a certain depth below the surface, the temperature maintains a nearly constant character during the circling changes of the year; and this permanent temperature is lower according as the place is more distant from the equator. We have before remarked, that the heat of the earth increases as we descend. The reverse of this takes place in ascending into the atmosphere; and on very high mountains we come to a region of perpetual snow, even under the equator. Enormous beds of clouds hang upon these mountains between the snowy region and the plains below, and increase the coldness of the mountain-tops, by interrupting the radiation of the caloric from the inferior parts. That increases the elastic power of the air; consequently, the equilibrium of the atmosphere, when unequally heated, must be constantly disturbed; the currents of warm and cold air change places, — the cold moving to the warm region, and thence, when warmed, repeating the course of the warm air. It will not be difficult, from this, to understand the cause of the sudden and violent changes of weather in very mountainous regions.

There is scarcely any subject in which mankind feel

themselves more interested than in the state of the weather; and it would be an amusing undertaking to calculate how much of our time is passed in telling one another it is hot, it is cold, it is fine weather, it is a beautiful day, &c. We have all been accustomed to see *clouds* from our infancy. They, therefore, neither awaken admiration, nor, in common cases, excite attention; yet, of all the objects around us, there are few more wonderful, or more truly deserving of notice. The traveller who has ascended high mountains knows that clouds are a species of fog, or mist, like those which we perceive upon plains; he has also remarked that, when the clouds are scattered in the air, the stratum of the atmosphere in which they float is comparatively dry. Clouds are composed of a mass of vesicles like soap-bubbles; these float in the air, rising or falling till they are in equilibrium with the air, remaining suspended thus as long as they preserve the same state. When the particles of vapor approach within a certain distance of each other, these minute water-drops have a tendency to unite, and presently fall in the shape of rain. Many of the phenomena in the formation of clouds cannot be fully explained; but we may be certain that, when a cloud is formed in the air, whatever be the cause, it can subsist there only while aqueous vapors continue to be produced in the same place. Thus the extent occupied by a cloud is an indication of the cause which produces vapors, or of its intensity in some part of this space. Extreme humidity exists but very little beyond the extent of the cloud, and as soon as the cause which furnishes the vapor ceases, the cloud dissipates.

The evaporation of clouds, even while they are increasing in size, is a circumstance of which we may easily be satisfied, by considering attentively the broken edge of a cloud which has a clear sky behind it. These edges present to the eye a thousand grotesque forms: often we perceive the part on which we are gazing dissipated in the place where it was first observed; often it stretches itself out, the cloud remaining stationary, and vanishes while it is thus extending itself. Sometimes, while one festoon vanishes, others are formed, by which the cloud is enlarged: at other times, the festoons successively evaporate, till the whole disappears. It is impossible to consider these various metamorphoses of the same cloud without supposing that there is, in the air, a source of vapors which are produced in the place where the cloud is formed, and that it is by the continual production of fresh vapor that the cloud subsists and increases, though continually evaporating. When they wholly disappear, it is because the evaporation is not repaired by the formation of fresh vapor. These phenomena are independent of heat and cold; for clouds are formed suddenly in the middle of a hot day, and after they have poured down their water, all is clear again. Sometimes they evaporate after sunset, gradually vanishing, in the calmest weather, without change of place. The appearances, on the whole, are such as would be produced by a large mass of water, in violent ebullition, suspended invisibly in the atmosphere; and the similarity in the effect naturally points out an analogy in the cause — that is, a source of vapor in the atmosphere.

When it rains, the source which furnishes vapors

produces them in such abundance that the vesicles are driven against each other, even in the bosom of the cloud, and, not having time either to disperse or evaporate, they are united; and the water falling to the lowest part, as in soap-bubbles, they are soon burst, and fall as rain. It is to these surcharged vesicles that we must attribute the pendent fringes which are sometimes seen under the clouds towards the horizon. Experience has shown that it rains under those clouds: not that these fringes are rain itself, but the vesicles which fall by the augmentation of their weight. As drops of rain are formed, the vesicles are destroyed. There is no sign of rain more certain than two different currents of clouds, especially if the undermost flies fast before the wind. When this happens in summer, there is seldom wind at the time, and thunder generally follows. In winter, the light vapor, or *scud*, as the sailors call it, often comes rapidly against the wind, and a gale is expected soon. The transparency of the air is, to the inhabitants of the Alps, one of the most certain signs of rain: when distant objects appear distinct and well-defined, when the sky is of a deep blue, they consider rain as near at hand, though no other signs appear. The same has been remarked in England and other countries. In such a state of the air, the sailors say the land, or other object, *looms* near, and predict bad weather. In the West Indies, it is observed that the stars look uncommonly large immediately before a hurricane.

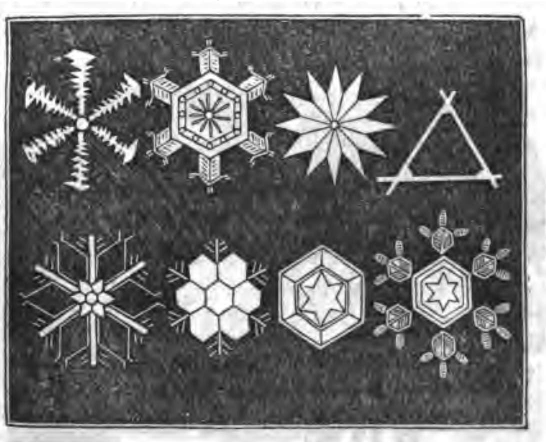
In Middle and Lower Egypt it never rains, and the excessive fertility arises from the flood of the Nile. The natives do not credit the phenomenon of water

falling from above. Hence it is that all monuments are so nicely preserved. Buckingham found a building which was left unfinished 3 or 4000 years since, with the ochreous marks of the workmen still perfect. A fog hangs for six months over Peru, and rain so seldom falls that a shower is a great calamity, since no precautions are taken against one.

Dew is the moisture which is deposited upon the surface of the earth, from the air, in the form of minute globules, resembling drops of rain. It is only deposited upon surfaces colder than the surrounding air. Some substances on the earth are found to grow colder during the night than others, and these receive the greatest share of dew. Deep water, which retains the heat received during the day, receives none at all; and animals sleeping in the open air remain perfectly dry, while the grass around them is covered with water. *Hoar-frost* is formed only upon very cold nights; the dew then freezes, and has a white appearance, like ice or snow. Dew is generally more plentiful in spring and autumn than in summer, because a greater difference is found between the temperatures of the day and night in the former seasons than in the latter. The formation of dew may be seen, on a smaller scale, in the collection of drops and moisture on the outside of a tumbler of cold water upon a sultry day. The tumbler, being colder than the air around it, condenses the air, and receives a portion of its moisture. The annual deposit of dew is about five inches deep.

Snow is found when the atmosphere is so cold as to freeze the particles of rain as soon as they are formed; and the adherence of several of these particles to each

other, which meet and cling together as they descend through the air, forms the usual fleeces of snow, which are larger in proportion as the clouds are higher, since they are longer in descending, and have more time to accumulate. By this means the heat of the earth is confined, and an admirable defence formed for the vegetable kingdom during the severities of winter. Snow-flakes usually consist of regular crystals, presenting many curious forms, which, when viewed through a microscope, appear as in the annexed cut.



Snow has been seen, in the polar regions, of a red, orange, and salmon color: this occurs both on the fixed and on floating ice, and appears in some cases to result from vegetable, and in others from animal matter, suspended in the sea, and deposited upon the ice around. Sometimes, natural snow-balls, an inch in

diameter, are formed by the rotation of the snow while falling. Snow-storms occasionally present a luminous appearance: one was witnessed in March, 1813, by a party on Loch Awe, in Scotland, which imparted to the glassy surface of the lake, the boat, their clothes, and all the surrounding scenery, a luminous appearance, like a huge sheet of fire. Their own bodies, to the eye, all seemed to burn; although, of course, without any feeling of warmth. When they applied their hands to any of the melting snow, the luminous substance adhered to them as well as the moisture, and this property was retained by the snow for twelve or fifteen minutes.

Masses of Ice in Polar Regions.

In the polar regions, the cold is so intense and invariable, that the ocean is generally encumbered by large fields of ice; and the air is frequently loaded with

dense and heavy fogs, by which navigation is rendered extremely perilous, and consequently, until lately, has been avoided by the most adventurous seamen.

The formation of *hail* has never yet been explained. Hail shows the existence of an intense degree of cold;— yet hailstones of an enormous size are formed during the hottest hours of the day in the hottest months of the year; and hail is more frequent in summer than in winter. The common notion is, that it is caused by the freezing of rain-drops; yet hail is usually formed in clouds that are very low in the atmosphere. It is highly probable that electricity has some extraordinary agency in its production. The descent of hail, in some countries, appears to occur at particular periods. In France, Italy, and Spain, it commonly hails most abundantly during the hottest hours of the day in spring and summer; and in Europe generally, it falls principally during the day, though there are examples of great hail-storms which have taken place during the night. That hail-storms have definite limits, may be inferred from the tremendous storm which desolated so great a portion of France in July, 1788. It began in the south-west, and proceeded in two parallel bands to the north-east, the extent of one of them being 175 leagues, and of the other 200,— thus traversing nearly the whole length of that great kingdom, and even a portion of the Low Countries. The mean breadth of the eastern band was four leagues, and of the western, two; and, what is very remarkable, the interval between the two bands, amounting to five leagues, was deluged with heavy rain.

This tremendous storm was ushered in by a dread-

ful and almost total darkness, which suddenly overspread the whole country. In a single hour the face of nature was so entirely changed, that no person who had slept during the tempest could have believed himself in the same part of the world. Instead of the smiling bloom of summer, and the rich prospects of autumn, which were just before spread over the country, it now presented the dreary aspect of gloomy winter and sterility. The fertile soil was changed into a morass; the standing corn beaten into a quagmire; the vines and the fruit-trees were torn to pieces; and the hail lay in heaps, like rocks of solid ice. The damage caused, in every part of the course of the storm, required years for its repair. This unforeseen and irresistible calamity, coming on when the popular discontent was leading rapidly to political dissensions, and when all men were looking for some great convulsion in the state, produced a singular effect upon the people, and had much influence in hastening the crisis of the revolution.

Hailstones are sometimes so large as to kill pigeons, ducks, and geese. A case is on record where hailstones were projected from a cloud almost horizontally, and their velocity was such that, in many instances, a clear round hole was left in the glass which they pierced, as if a bullet had been shot through it. In referring hail to an electrical origin, we may explain the oblique discharges by supposing two electrical clouds drawn towards each other. Arago remarks that sometimes, before the descent of hail, a crackling noise is heard, which it would be difficult to describe in any other way than by comparing it to the emptying a bag

of walnuts. This is accounted for, by some meteorologists, by supposing the hailstones to be driven by the wind against each other in the clouds which carry them. Others imagine the hailstones themselves to be strongly and differently electrified, and consider the crackling in question to result from electrical discharges a thousand times repeated.

Thunder and *lightning*, we have already shown, are caused by electricity; but the cause of the thunder-clap, which accompanies the flash, is still the subject of conjecture. In general, it is considered that lightning, by its heat, creates a partial vacuum in the atmosphere, and that the sudden rushing of air into the void space produces the sound; but various reasons have been assigned for the long-continued noise of thunder. It was formerly supposed that the rolling sound is merely the result of several echoes caused by reflection from mountains, woods, buildings, or clouds, or from the latter alone when a thunder-storm takes place over the ocean. This opinion seems to have been founded upon the fact, that the report of a gun, discharged in a mountainous region, is prolonged by the echoes during at least half a minute, which is about the time that the rolling of thunder continues. But, though the reflections of sound are very probably, in part or at times, the causes of the prolongation of thunder, they do not always afford a satisfactory explanation of the phenomenon, which, in a great many cases, cannot be accounted for by the doctrine of echoes. Possibly, the rolling may arise from the circumstance that there are several points of explosion, at different distances from the ear.

The flash of lightning, and the explosion of the

thunder, take place in reality at the same moment; but as sound travels at the rate of 1125 feet in a second, while the passage of light from the cloud to the observer may be considered as instantaneous, it follows that, on counting the number of seconds which elapse between the time of seeing the flash and hearing the report, the distance of the thunder-cloud from the observer may be ascertained, if 1125 feet be multiplied by that number of seconds. From the observations of the voyagers toward the north pole, it appears that neither thunder nor lightning is known beyond the 75th degree of latitude; and even as high as the 70th degree, they are extremely rare.

Winds are occasioned by whatever disturbs the equilibrium of the atmosphere, or the equal density or quantity of air at equal distances from the surface of the earth — whatever accumulates the air in one place, and diminishes it in other places. Heat, which rarefies, and cold, which condenses the air, are by far the principal and more general causes which produce currents in the atmosphere. Another cause has been ascribed to the attraction of the sun and moon, whose influence is supposed, with great probability, to occasion a tide, or flux and reflux, of the atmospherical fluid, similar to that of the sea, but greater, because the air lies nearer to those celestial bodies, and because air is incomparably more expansible than water. Some action in the production of the wind may also be derived from volcanoes, fermentations, evaporations, and especially from the condensation of vapors; for we find that, in rainy weather, a considerable wind frequently precedes the approach of every single cloud, and that the wind

subsides as soon as the cloud has passed over the zenith.

Winds are phenomena in a great measure dependent on the law, that lighter fluids rise in heavier ones. As oil, let loose under water, is pressed up to the surface, and swims, so air, near the surface of the earth, when heated and expanded by the sun, rises to the top of the atmosphere, and spreads there, forced up by the heavier air around, which rushes inward, and constitutes wind. The cross currents in the atmosphere, thus arising, are often rendered evident by the motion of clouds or balloons. If our globe were at rest, and the sun were always shining on the same part, the earth and air directly under him would become exceedingly heated, and then the air would be constantly rising, like oil in water, or the smoke from a great fire — which currents or winds would be pouring towards the central spot from all directions below. But the earth is constantly turning round under the sun, so that the whole middle region, or equatorial belt, becomes heated; therefore, according to the principle just laid down, there should be over it a constant rising of air, and constant currents from the two sides of it, on the north and south, to supply the ascent. Now, this phenomenon is really going on, and has been going on ever since the beginning of the world, producing the steady winds of the northern and southern hemispheres, called the *trade winds*, which prevail in most places within 30 degrees of the equator, and on which mariners reckon almost as confidently as on the rising and setting of the sun.

The trade winds, however, do not appear on the earth

to be directly north and south, as they are in fact; for the eastward whirling, or diurnal rotation, of the earth, causes a wind from the north to appear as if coming from the north-east, and a wind from the south as if coming from the south-east. This is illustrated by the case of a man on a galloping horse, to whom a calm appears to be a strong wind in his face; or, if he is riding eastward, while the wind is directly north or south, such wind will appear to him to come from the north-east or south-east. While, in the lower regions of the atmosphere, air is constantly flowing towards the equator, and forming the steady trade winds between the tropics, in the upper regions there must, of course, be a counter-current, distributing the heated air over the globe. This has been confirmed by many observations. At the summit of the Peak of Teneriffe there is always a strong wind, blowing in a direction contrary to that of the trade wind on the face of the ocean below; and, among other proofs, we may specify the following singular incident: —

On the 30th of April, 1812, about midnight, the inhabitants of the Island of Barbadoes were roused from their sleep, and greatly alarmed, by a sound like that of a heavy cannonading, and a light similar to the flashes from guns was seen in the west. It was supposed to be a naval action between a British and French fleet. The troops were beat to arms, and all were put in readiness to act as the emergency might require. The firing increased towards morning, but afterwards the sound died away. All this time the sky was perfectly clear and serene; but soon after dawn, thick masses of clouds collected over the island, and

poured down, instead of rain, torrents of an earthy dust finer than sand. The sun rose invisible, and all nature was wrapped in darkness more intense than ever was known in the blackest midnight. The alarm of war immediately gave place to more appalling thoughts; all were thrown into indescribable consternation. Many persons apprehended, and not without reason, that the end of the world had come; and the affrighted multitude thronged to the churches, groping their way with lanterns in their hands. It was not till 20 minutes past noon that a gleam of light afforded a feeble hope to the dismayed population. In the afternoon, the falling of the dust gradually abated, and the sky slowly became clear, and dissipated their fears. The dust had fallen in some places six inches in depth. A ship 500 miles eastward of Barbadoes had her sails and decks covered with it. On being analyzed, it proved to be volcanic; and 5 days afterwards, a vessel arrived from St. Vincent's with the intelligence, that the Souffrière, a volcano in that island, had burst forth in flames, and laid the whole colony in ashes. All this time the regular trade wind had been blowing from the eastward, which should have carried the ashes away from Barbadoes, that island lying 70 miles to windward of St. Vincent's; but the volcano had thrown its contents above the trade wind into a contrary current of air, and thus the ashes had been transported upwards of 500 miles, apparently against the wind.

Beyond the tropics, where the heating influence of the sun is less, the winds occasionally are subjected to other influences besides those which we have described, but which have not yet been well explained. In many

situations beyond the tropics, the westerly winds, which are merely the upper equatorial currents of air falling down, are almost as regular as the easterly winds within the tropics. Voyages from the United States to Europe are usually shorter than voyages home. While the sun is beaming directly over a tropical island, he heats the surface of the soil, and therefore the air over it; but the rays which fall upon the ocean around, penetrate into the water, and the superficial increase of temperature is less. In consequence of this, there is a rapid ascent of hot air over the island during the day, and a cooler wind blowing towards its centre from all points. This wind constitutes the refreshing *sea-breeze* of tropical islands and coasts. During the night, an opposite phenomenon takes place. The surface of the earth, then no longer receiving the sun's rays, is soon cooled, while the sea, which absorbed heat during the day, not on the surface only, but through its mass, continues to give out heat all night. The consequence is, that the air over the earth, being colder than that over the sea, sinks down and spreads out on all sides, producing the *land-breeze* of tropical climates. This wind is often charged with noxious exhalations from the marshes and forests, while the sea-breeze is all purity and freshness. Many islands and coasts would be totally uninhabitable but for their sea-breezes.

In the East Indian seas a periodical, or trade wind, called the *monsoon*, blows half the year in one direction, and half the year in the opposite. These directions are different in different places; in some north and south, in others north-east and south-west. The change of the monsoon is announced by calms and

squalls in rapid succession, waterspouts, tornadoes, and hurricanes called *taifouns* or tuffoons, particularly terrible from the explosions of electric matter accumulated during the monsoon.

We come now to the most interesting and important subject in meteorology—the philosophy of storms and hurricanes; and here it is somewhat mortifying to the pride of science, that we know so little of the true cause of these terrible perturbations of the atmosphere. When the paroxysms of heat and cold smite the organizations of animal and vegetable life; when the swollen cloud pours down its liquid charge, and menaces us with a second deluge; when the raging tempest sweeps over the earth with desolating fury; when the electric fires shiver the fabrics of human power, and rend even the solid pavement of the globe,—when all the powers of the air are thus marshalled against him, man trembles upon his own hearth, the slave of terrors which he cannot foresee, the sport of elements which he cannot restrain, and the victim of desolation from which he knows not how to escape.

The East and West Indies are the countries in which hurricanes most frequently exercise their ravages. The hurricanes of the northern parts of the globe are not, in any way, to be compared to those of the equatorial regions. Generally speaking, the former are nothing more than whirlwinds occasioned by the meeting of two opposite currents. But, in a real hurricane, all the elements seem to have combined and armed themselves for the destruction of nature. The lightnings cross each other, the thunder roars without interval, rain falls in torrents, and the velocity of the

wind far exceeds that of a cannon-ball. A West India hurricane is generally preceded by an awful stillness of the elements; the air becomes close and heavy, the sun is red, and the stars at night seem unusually large. Frequent changes take place in the barometer and thermometer; darkness extends over the earth; the higher regions gleam with lightning. Sometimes, a little black cloud appears on the summit of a mountain; and at the instant when it seems to settle on the peak, it rushes down the declivity, spreads out, and covers all the horizon. At other times, the tempest advances in the semblance of a fire-colored cloud showing itself suddenly in a calm and serene sky.

The most celebrated hurricane on record is, perhaps, that which desolated the Island of Barbadoes in 1831, and was attended by the most singular meteorological phenomena ever witnessed. The month of July, in that quarter, had been more than usually rainy; but the trade wind blew moderately and steadily from the proper quarter, and the temperature was remarkably uniform. Much thunder and lightning occurred toward the end of the month, and in the first week of August. On the 10th of August, the sun rose without a cloud, and shone resplendently through an atmosphere of the most translucent brightness. Calms, and slight puffs of wind, prevailed throughout the day, and the thermometer stood at 88 in the afternoon. At 5 o'clock, the clouds began to gather fast in the north, and the wind commenced blowing strong from that point. A shower of rain fell, after which there was a remarkable stillness, made more impressive by the dismal darkness of the clouds on the horizon all around. This dark,

impenetrable body extended up toward the zenith, leaving there an obscure circle of light of a dismal hue, which remained at rest but a few seconds only, when the scud of the cloud was seen in a state of ebullition. The dense mass around was also agitated and separating, and bodies of it were dispersed to all points of the compass. At 7 in the evening, the sky was clear again, and the air calm. At 10, came on showers, lightning, and squalls; after midnight, the continual flashing of the lightning was awfully grand, and a fierce gale blew from the north-east.

But these phenomena were slight in comparison to what soon followed. At 1 in the morning, the tempestuous rage of the wind increased, and the storm shifted suddenly to the north-west. The upper regions of the air were from this time illuminated by incessant lightning; but the quivering sheet of blazing fire was far surpassed in brilliancy by the darts of the electric fluid, which were exploded in every direction. A little after 2 o'clock, the astounding roar of the hurricane came on with a terrible impetuosity that no language can describe, nor mind conceive. Those who witnessed it compared it to the agonizing shrieks of millions of human beings in the last horrors of despair; and they affirm that there was something indescribably piercing and heart-rending in this wailing scream, which never ceased till the end of the hurricane. About 3, the wind occasionally abated, but only to return in gusts from the south-west, west, and north-west, with accumulated fury. It was now that the most portentous and appalling apparitions added new

horrors to the scene. The heavens appeared all in flames, with balls of fire flying in all directions, and bursting like shells from a mortar. One of them was seen of a globular form, and deep-red hue, descending perpendicularly from a great height; on approaching the earth, its motion was accelerated, it became of a dazzling whiteness, and elongated in form, — and, dashing on the ground in one of the paved squares of Bridgetown, it splashed around in the same manner as melted lead would have done if thrown out of a furnace, and became instantly extinct, though the brilliancy and spattering of its particles, when it reached the earth, gave it the appearance of a globe of quicksilver.

A few minutes after the appearance of this phenomenon, the deafening noise of the wind sank into a solemn murmur, like a distant roar; and the lightning, which, since midnight, had played in flashes and forked darts with scarcely any intermission, seemed, for half a minute, to hover between the clouds and the earth, moving frightfully, and with a novel and surprising action. There seemed to be a vast body of vapor, almost touching the houses, which apparently caught fire from the clouds, and conveyed it flaming downwards, while, again, a thousand torches were lighted from the earth, and mounted to the sky. While this strange phenomenon continued, the earth was felt to vibrate in a manner, and in time, answering with the action of the lightning. Twice, or more, when the coruscations were more brilliant and severe, but less rapid in their motion, the earth received corresponding shocks. The moment this singular alternation of the lightning passing to and from the earth ceased, the

hurricane again burst from the west, with a violence exceeding all that had as yet been experienced, and hurling every thing, in fragments, before it. Masses of lead weighing 400 pounds were carried above a quarter of a mile; the strongest buildings vibrated to their foundations, and the very surface of the earth trembled as the destroying blast passed over it. The storm absolutely out-roared the thunder, and the latter was not even heard. All witnesses concur in affirming that, had the cannon of a thousand batteries been discharged, their sound could not have been distinguished, so overpowering was the roar of the wind, and the howling of the tumultuous ocean, whose frightful waves threatened to sweep into the abyss all that the other elements might spare.

Those who describe this scene declare it to be impossible to express, in language, the sensations which then distracted and benumbed their faculties. The sight and hearing were overpowered by the horrors around them, and many even lost their senses. One person, on coming to himself, found that he was standing up against the wall of the room in which he was sleeping when the hurricane commenced; the roof, and every article in the room, had been carried away; how he escaped destruction he knew not! After 5 o'clock, there were occasional lulls in the storm — during which, the falling of substances which had been carried high into the air, the shrieks of suffering victims, the cries of the terrified inhabitants, and the mournful howling of the dogs, were all distinctly heard, and awakened in the mind of the listener a fearful appreciation of the scenes of death and misery by which he was surrounded. At

10 in the morning, the sun looked out upon a scene of devastation such as, perhaps, was never before witnessed. The humble cot, and the most costly mansion, had been alike hurled to destruction. Parents beheld their children, and children their parents, buried in ruins, or their disfigured corpses strewed around. Others, with fractured limbs and dreadful mutilations, were still alive, under fallen buildings, uttering heart-rending cries of agony. Between 2000 and 3000 persons were killed or mortally injured, and the wounded exceeded 5000. Houses were lifted up from their foundations, and thrown, in one mass of ruins, into the roads. Masses of rubbish and fragments were scattered in every quarter. The whole face of the island was laid waste; scarcely any sign of vegetation existed; and what remained was of a sickly-green color. The surface of the earth appeared as if fire had passed over it, scorching and burning up every thing. The few trees that were left standing were stripped, and the bare, withered trunks were all that remained.

There are other phenomena in hurricanes which have been in part explained by the researches of men of science who have recently turned their attention to this subject. Sometimes, a perfect calm happens in the midst of the tempest, after which it comes on again as furiously as ever, and in a direction opposite to the first. The master of a ship lying at the Island of St. Thomas says, "In the morning, the wind was north and north-west; in the afternoon, violent squalls forced me to anchor in 10 fathoms' water. At 5, the squalls were succeeded by a gale, and at 7 a hurricane arose, beyond all description dreadful. The windlass

capsized, and I could not slip my cables, the ship driving till I was in 20 fathoms of water A calm then succeeded for about 10 minutes; and then, in the most unearthly screech I ever heard, it recommenced from the south and south-west." In another hurricane, the wind blew above 12 hours with the utmost fury from the north-east, and then, in an instant, a perfect calm ensued for an hour. Then, "quick as thought, the hurricane sprang up with tremendous force from the south-west, no swell whatever preceding the convulsion. The wind resembled numberless voices, elevated to the shrillest tone of screaming." To another vessel which was caught in this hurricane, a most extraordinary phenomenon presented itself to windward, almost instantaneously. It resembled a solid, black, perpendicular wall, about 15 or 20 degrees above the horizon, and disappeared almost in a moment. It then reappeared as suddenly, and in 5 seconds was broken and spread as far as the eye could see. The narrator describes this as the most appalling sight which he had ever seen. An officer, on board a British ship of war, in describing a hurricane which overtook her on the American coast, in 1814, states that, after the wind had blown 4 hours, with a tremendous sea, the barometer sank very low, and the scenery of the sky became indescribable. "No horizon appeared, but only something resembling an immense wall within 10 yards of the ship. She was immediately thrown upon her beam-ends, and the topmasts were blown away without any person hearing the crash." But perhaps the most remarkable phenomenon exhibited by a hurricane was in 1837, and described by Captain Seymour, of Cork. "For nearly

an hour we could not see each other, nor any thing else, but merely the light; and, most astonishing, every one of our finger-nails turned quite black, and remained so nearly 5 weeks afterwards." This fact may be classed among other proofs of the agency of electricity in the production of hurricanes.

Great light has recently been thrown upon this subject by the labors of our ingenious countryman, Mr. Redfield, of New York; and it is now rendered extremely probable, if not quite certain, by a body of evidence collected by him, that in all or most of the great storms which agitate our atmosphere, the wind has a *rotatory* movement; that the diameter of the circle within which the gyration is performed is sometimes several hundred miles; and that this whirlwind has a *progressive* as well as revolving motion. Thus, in the gale of the 15th of December, 1839, the wind was easterly at Boston, Newburyport, Portsmouth, and Portland; northerly along the course of the Hudson; south-easterly at Nantucket; westerly at sea farther south; and in corresponding directions at the intermediate points. By marking down these upon a map, the circular shape of the storm is fully demonstrated; and we ascertain the important fact, that the direction of the wind at a particular place forms no part of the essential character of the storm, which is, in all cases, compounded of both its rotatory and progressive velocities.

It appears that the violent gales which are experienced on the coast of the United States are prolongations of the West India hurricanes or whirlwinds. They originate among those islands, covering simulta-

neously an extent of surface from 100 to 500 miles in diameter, acting with great energy near the centre, but with diminished violence at the exterior. South of the 30th degree of latitude, these whirlwinds move westerly, gradually inclining to the north till they approach the 30th parallel, when their course changes abruptly to the north and eastward, the track continuing to incline gradually to the east, towards which point they continue to advance with an accelerated velocity. Thus, to specify one out of numerous examples: — In 1804, a hurricane swept over the Windward Islands on the 3d of September; the Virgin Islands on the 4th; Turk's Island on the 5th; the Bahamas on the 6th; the coast of Georgia and Carolina on the 7th; Virginia, Maryland, and New Jersey, on the 8th; Massachusetts, Maine, and New Hampshire, on the 9th, — becoming a violent snow-storm on the White Mountains. It performed a journey of 2200 miles in about six days, at the average rate of about fifteen miles and a half per hour. More violent hurricanes have travelled at double this speed.

In these whirlwinds, the rotatory movement is always from right to left, or contrary to the movement of the hands of a watch; in the storms of the southern hemisphere, the reverse is the case. Knowing, therefore, the direction in which the storm is travelling, a ship-master, on being overtaken by it, may shape his course so as to sail out of it, or towards the exterior edge, where its violence is least. From a lack of this knowledge, many a ship has been steered into the heart of a storm, and lost, when she might have escaped by taking a contrary direction. In the very centre of the vortex is a calm

spot; and whenever this passes, the phenomenon occurs, which we have already described, of the wind falling suddenly calm, and then springing up from the opposite quarter with the same fury as at first: this is perfectly explained on the supposition of a gyrating circle. The barometer always falls in the beginning of a storm, and continues to fall till the centre of the circle has passed, after which it rises. This is ascribed to the centrifugal tendency of the immense revolving mass of atmosphere that constitutes a storm, which action must expand and spread out the stratum of air exposed to its influence.

The nature of the soil over which the wind blows has a great effect upon the quality of the air. The vast sandy deserts of Africa and Arabia give a burning heat and a blasting quality to the air that passes over them. On the coast of Guinea, there is a wind from the interior called the *harmattan*, which scorches the skin of those who are suddenly smitten by it like a blast from a furnace. An extraordinary scorching wind is felt occasionally at the Falkland Islands. It cuts down the herbage like a fire: the leaves are parched, and crumble to dust: fowls are seized with cramps so as never to recover; and men are oppressed with sore throats and difficulty of breathing. But more dreadful than all others is the *samiel*, or *simoom*, the deadly wind of the deserts of Arabia and Africa. The camels, either by instinct or experience, have warning of its approach, and announce it by an unusual noise, and by covering up their noses in the sand. To escape its effects, travellers throw themselves on the ground with their faces downward, and wait till it has passed

by, which is commonly in a few minutes, although it sometimes continues much longer.*

The AURORA BOREALIS, or NORTHERN LIGHTS, will occur to the reader as the most splendid of all meteorological phenomena. They appear in the northern part of the heavens for the most part, and generally in frosty weather. Some very splendid exhibitions of this phenomenon have recently been witnessed in the United States; but in general we have but a faint notion of the brilliancy and magnificence with which it appears in the northern parts of the globe. In the Shetland Islands, *merry dancers*, as they are called, are the constant attendants of clear evenings, and prove a great relief amid the gloom of the long winter nights. They commonly appear at twilight, near the horizon, of a dun color; sometimes continuing in that state for several hours without any sensible motion; after which they break out into streams of stronger light, spreading into columns, and altering into ten thousand shapes and colors. They often cover the whole heavens, and amaze the beholder with the rapidity of their motion and change of form; they commonly have a strong tremulous motion from end to end. Sometimes they assume a deep blood-red color, and strike a great terror into the spectators.

Hardly any phenomenon has excited more curiosity than the aurora borealis; yet we know little more of its cause than the fact that electricity has a share in it. It was a much more rare appearance formerly than

* For an example of the dreadful effects of the *simoom*, see "Lights and Shadows of African History," p. 198.

at present. In England, it was hardly seen during the whole of the 17th and the early part of the 18th century. In Sweden, where it is now almost perpetual, it was a great rarity before 1716. There is also an *aurora australis*, or *southern light*, in the southern polar regions; but it is neither so common nor so brilliant as that of the north.

CHEMISTRY.

Chemistry is that science which investigates the mutual agencies of the elementary principles of matter. It attempts the resolution of all compound bodies into their simple constituent parts; and it examines the action of these elements upon each other, as well in their simple state as in their varied forms of combination. Chemistry acquaints us with the means of performing the most important changes in the properties of bodies. It is a science, the utility of which is as boundless as its extent. The growth and preparation of articles of food, and every process on which the comforts of life and the daily labor of man are dependent, can improve only with our knowledge of the properties of bodies which are the instruments we must use to minister to our wants.

Chemistry, according to the definition which we have given of it, is a science of but recent date, and can scarcely be said to have existed above two centuries. But it has been usual to connect its history with the science of *alchemy*, or the supposed art of transmuting baser metals into gold, and of preparing a universal medicine. Many alchemists professed to have obtained the secret of metallic transmutation, and, by the help of skilful legerdemain, some well-attested instances of their successful operations are on record. Few, how-

ever, were, like Paracelsus, bold enough to declare that they had discovered the *elixir of life*, by which human existence might be prolonged to an indefinite period of duration. It is needless to say that these few gave an unfavorable proof of their success by living no longer than common mortals. Yet even these were not without some reason in their folly, for the operations of chemistry had recently so prepared some metallic bodies as to render their effects little short of miraculous in arresting the progress of disease; therefore they might well hope to see still greater effects produced by further investigations. Alchemy is, therefore, considered the parent of chemistry, although the objects of the two sciences differed materially. The chemists found the instruments of the alchemists ready fitted to their hands: they found, also, some useful facts recorded, though their number was by no means equivalent to the labor and the time that had been expended in amassing them. At the dawn of chemical science, the wisest of the alchemists, quitting their ancient chimerical pursuits, embarked in the legitimate process of experimental chemistry.

The alchemists, from a desire to conceal their self-delusion, or to excite admiration by the appearance of having accomplished their designs, were anxious to give every product of their laboratories a mysterious, extraordinary, or unintelligible name. Such designations as *horn moon*, *mercury of life*, the *wonderful salt*, and the *salt of many virtues*, form but a small specimen of a prodigious number of names equally inappropriate and ridiculous. Hence, when the dreams of alchemy were broken by the dawn

of a more enlightened day, when men who had the promulgation of truth only for their object became chemists from a persuasion of the advantages which the cultivation of that science would afford to mankind, they found it difficult to unravel the confusion caused by the absurd names thus bestowed upon the materials of their science. This evil was not completely remedied till toward the close of the last century, when the French chemists took the lead in reforming the chemical nomenclature, and bestowing upon all substances significant, systematic, and philosophical names.

To acquire a knowledge of those properties of matter, the investigation of which belongs to chemistry, two methods are employed. The one is that of *analysis*, or decomposition; the other is that of *synthesis*, or composition. By the one, the different simple substances of which compound bodies consist are separated, and their properties individually examined; by the other, the simple substances are combined together, and the properties of the new compound are investigated. Different modes of analysis have been admitted and described by chemical writers. Some bodies, when exposed to the action of heat and air, undergo a total separation of their component parts; this is called *spontaneous* analysis; — thus some minerals, and all vegetable and animal matters, when deprived of life in favorable circumstances, slowly separate into their component parts; and in the same way, the principles of which some liquids are composed react on each other, and spontaneously separate, thus giving an opportunity of investigating the nature of these substances.

Analysis by fire operates by the accumulation of caloric in bodies, and by the power which it has of separating their particles, thus favoring their examination. Another mode of analysis is by re-agents. This is conducted by placing the compound body, which is to be examined, in contact with various substances which have the power of separating its constituent parts; this is always done by forming a combination with one of the constituents, to the exclusion of others. It is here that the genius and science of the chemist appear most conspicuous; for every substance in nature, and all the products of art, become valuable instruments, in his hands, to ascertain the nature and investigate the properties of the substances which come under his examination.

Synthesis, or composition, is the union of two or more simple substances. This union, from whence a new compound results, has become an important step in exploring the properties of bodies, and in forming a number of products useful in the arts, and necessary to our wants; and thus it is considered by chemists — being in some measure the inverse of the method of analysis — as the perfection of their art, and one of the great instruments of their operations. The method of synthesis is, in reality, more frequently employed than that of analysis; and the name of the science, if we regard these two methods, should rather be the *science of synthesis* than the science of analysis. There are many bodies which have never yet been decomposed; and it is only by combining them with others, and examining the nature of the compounds

thus formed, that the chemical properties of these bodies can be investigated.

Bodies exist in three different states, which are quite distinct from each other, — namely, the solid, the fluid, and the fluid-elastic state. Solidity is supposed to be the consequence of the irregular figure of the atoms of matter, and their great deviation from the spherical form, by which free motion among them is prevented. The atoms of fluid bodies are supposed to be spherical, and their forces are more directed to their centres than to their surfaces, by which motion is freely allowed when any force is applied. Fluids are divided into three kinds: one in which the particles have no mutual power, as sand and fine powders; one in which they have a repulsive power — such are the elastic fluids, as air; and the third, in which they have an attractive power, as water, mercury, &c.

There is also a class of bodies intermediate between the solids and fluids; these are the *viscid* substances, the particles of which attract each other more strongly than the fluids, but not so strongly as the solids. In these bodies, the particles deviate so far from the spherical form as to produce a certain resistance among each other, and to impede their relative motion.

According to the above explanations, all chemical phenomena may be traced to the same principle — namely, the law of the forces, and the differences in the particles which thus arise. *Solution*, for instance, is thus explained. The particles of some solid bodies have less attraction for each other than for the particles of some fluids; and, consequently, when these are applied to each other, the particles of the solid separate,

and combine with those of the fluid, forming a mixture of the two. But the separation of the particles of the solid can only take place so long as the particles of the fluid are in the sphere of their attraction; and when either of them get beyond it, or when the attraction of the mixture thus formed becomes equal to the attraction of the particles of the solid for each other, no further solution takes place, and the fluid is said to be *saturated*. But if into this mixture another solid, whose particles have a greater attraction for the fluid, be introduced, the fluid will leave the former solid, and combine with the particles of the latter: the particles of the former will fall to the bottom, and *precipitation* will take place.

Substances which are dissolved may not only be obtained again by precipitation, but also by slowly abstracting part of the fluid in which they are dissolved. This is called *evaporation;* and the solid bodies, which are thus slowly formed, generally assume some regular shape, and are denominated *crystals.* As the fluid is removed, the particles come gradually into the sphere of the attractive power of each other, and thus attain some degree of cohesion when the fluid which kept them asunder is removed. But when a solid is obtained by precipitation, the fluid is suddenly removed from between the particles, which are consequently left beyond the sphere of attraction of each other, and do not, therefore, assume any regular form. And thus it will follow that, the more slowly the process of evaporation goes on, the more regular will be the crystals which are formed; and this corresponds with experiment and observation.

Bodies which are composed of particles of the same nature cohere with a certain force, as in the particles of water or of mercury, and those of wood or of metal; and this force acts with different degrees of intensity: in water and mercury, it is comparatively weak; but in wood and metal, it is very powerful. But the particles of dissimilar bodies also enter into combination, and, thus united, form substances, the parts of which cohere with great force; and whenever these combinations take place, the force of cohesion, formerly subsisting between the particles of each of the bodies, must be destroyed or overcome, before the new combination can take place. Thus a piece of marble is dissolved in muriatic acid; but before this can take place, the force of cohesion which existed between the particles of the marble must be overcome; or, in other words, the force of attraction between the particles of the muriatic acid and the particles of the marble must be greater than that between the particles of marble themselves. This attraction, which exists between the particles of substances of a different nature, is called *chemical affinity*.

This attraction, or affinity, does not exist between the particles of all bodies. Thus there is no affinity between marble and water, as there is between marble and muriatic acid: water has not strength enough to overcome the attraction opposed to it; and it has been thought that there is no affinity between oil and water, because the particles of the one do not enter into combination with those of the other.

Fourcroy has arranged the facts which depend on chemical affinity under ten different heads, denomi-

nated the *laws of affinity*. These may be considered as chemical axioms, which are the principles or foundations of the science. They are as follows:—

1. Chemical affinity takes place only between bodies of a different nature.

2. Chemical affinity takes place only between the ultimate particles of bodies.

3. Chemical affinity takes place between several bodies.

4. In order that chemical affinity may take place between two bodies, it is necessary that one of them be in a fluid state.

5. When bodies combine together, they undergo a change of temperature.

6. The compounds formed by chemical affinity possess new properties, and different from those of their constituent parts.

7. The force of chemical affinity is estimated by the force which is required to separate the substances which enter into combination.

8. Bodies have different degrees of affinity for each other.

9. Affinity is in the inverse ratio of saturation.

10. Between two compound bodies, which are not acted upon by compound affinities, decomposition may take place, if the affinity of a compound, consisting of two of the principles, for a third, be greater than that which unites this third to one of the two first, or to the fourth principle—although, at the moment of action, the union between the first two does not exist.

We shall now proceed to describe those properties of matter which are strictly chemical; but a part of

this work has been anticipated by a previous chapter. Upon these properties, numerous classifications have been founded; and although in part abandoned at the present time, in favor of other terms more rigidly chemical, yet we so frequently use the words *airs*, *earths*, *metals*, *alkalies*, *acids*, &c., that it will be proper briefly to enumerate the leading characteristics of these substances.

The word *air* is sometimes employed to designate all the permanently elastic fluids, and, in this sense, it is synonymous with the word *gas;* but it is more commonly restricted to the atmospheric air — a mixture principally of two gases — in which we live and breathe.

The term *earths* is still applied to one class of substances, though rather loosely; for it has been found that, in all general chemical properties, the earths and the metallic oxides are the same, and nearly all the earths have metallic bases. Earths have been described as insipid; soluble, but in very small proportion, in pure water or oil; not inflammable, not ductile, and not fusible, by themselves; but recently the powers of the Voltaic pile, and the gas blowpipe, have shown that they are fusible; and the alkaline earths cannot be termed insipid.

Of the *metals* we shall speak hereafter. Their two essential chemical properties are, the power of conducting electricity, and the possession of some degree of lustre. They are all capable of combining with oxygen, though with very different degrees of facility.

The *alkalies* are a well-marked, though not a numerous, class of bodies. The term *alkali* is derived from the Arabic name of the plant from which one of these

substances has long been extracted. The general properties of the alkalies, especially as developed in the stronger ones, are as follows: they change blue vegetable colors to green; and if such colors have been changed to purple, or to a more vivid red, by acids, they destroy that sort of action, and, when used in sufficient quantity, turn them absolutely green. The same power they possess even when saturated with carbonic acid,—a property which does not belong to the alkaline earths. Their taste is acrid, probably arising, in a great degree, from their power of dissolving all animal matter with an energy proportioned to their state of concentration. They readily combine with oils or fatty substances, so as to form soaps. Their carbonates are soluble in water, but the carbonates of the alkaline earths are not so. Three of the alkalines consist of metallic bases united with oxygen, namely potassa, soda, and lithia. One, ammoniac, consists of two gases, hydrogen and nitrogen; and the vegetable alkalies, which are rather numerous, consist of various combinations of oxygen, hydrogen, and carbon.

The term *acid* is in familiar use, and is generally understood by all; its chemical sense is, in fact, adopted from ordinary language. Acids are substances having a sour taste; they are frequently highly corrosive of animal and vegetable bodies, and they change purple vegetable colors to a brighter red. Their most distinctive chemical property is, that they unite with other substances, called *bases*, such as the alkalies, the earths, and metallic oxides, and form new classes of bodies, called *salts*, in which the antagonist

properties of both acid and base undergo great modifications, or are absolutely annihilated. The theory of acidification — that is, the effective cause of producing acid properties — has not yet been well explained.

In a chemical sense, substances are divided into two kinds, simple and compound. Simple bodies are those which have not been separated into others more simple, nor reproduced by artificial means. The ancients considered four substances as simple and uncompounded, which they denominated elements, — namely, *fire*, *air*, *earth*, and *water*. But these have all been decomposed, and their constituent parts well ascertained. The number of simple substances is constantly changing, as new discoveries are made. They are at present divided into two classes; the one called *combustible*, or inflammable, and the other *supporters of combustion* — because, in combining them with the first class, much light and heat are developed. Most of the simple combustibles have been proved to be metals, and hydrogen is believed by some to be a metal in an elastic form.

Caloric, or heat, is a most important agent in chemistry. Its general tendency is, to keep the particles of matter at a certain degree of expansion. It pervades all things, but some in a greater degree than others. Even ice has been found to contain a certain portion of heat. In fact, there is no such thing in nature as positive cold; the things that seem cold to us are only under a low degree of heat. The absolute nature of this universal principle is unknown; we only know it by its effects and the sensations it produces. Some have conjectured that it is a fluid; others think it a quality

or affection of matter, resulting from chemical action. From its producing no sensible difference in the weight of any substance, it has been called an *imponderable body*. When the heat of any particular substance, as ice, stone, or wood, is not sensible to us, it is called *latent* or *concealed* heat. We may very readily detect its presence in a piece of wood or metal by friction. If a button, for instance, be rubbed on a table, it will soon become too hot to be held by the fingers. In like manner, the axle of any carriage-wheel soon becomes hot unless the friction is prevented by grease.

The chemical effects of heat are expansion, liquefaction, vaporization, evaporation, and ignition. With few exceptions, bodies are capable of *expansion* by means of heat; the gases being the most expansive, fluids less so, and solids least of all. When the iron rim of a coach or cart-wheel is to be put on, it must first be heated to a considerable degree. The reason of this is obvious; when hot, the circle is larger than when cold, and thus slips easily on the wheel: as it cools, the circle decreases, and thus firmly binds the wood-work together. As regards fluid bodies, the same fact is illustrated in the case of the thermometer and barometer; by the accession or loss of heat, the mercury expands or contracts to a degree indicated by the scale annexed to the instrument. The general law, therefore, is, that the expansion and contraction of matter are, with a few exceptions, dependent upon the increase and diminution of heat. The quantity or condition of heat that is discoverable by the thermometer, or by the organs of sensation, is called *temperature*.

Vaporization is the rapid production of a thin vapor,

as when water is converted into steam. The boiling point of water, in a vessel exposed to the ordinary atmospheric pressure, is 212 degrees of Fahrenheit; and, although more heat be applied to the vessel in which it is contained, the temperature of the water is not increased. If this degree of heat be continued, the watery particles separate from each other, and become steam or vapor. Steam is colorless, transparent, and invisible, resembling the atmosphere; and is 1696 times greater in bulk than its weight of water. Steam may be condensed, or its particles brought nearer to each other, either by removing the heat which is the cause of the vaporization, or by mechanical pressure; and the result is, its return to the form of water.

Distillation is the converting of a liquid into vapor, which is afterwards carried off through a pipe, and condensed in what is called a *refrigerator*. This is a vessel filled with cold water, round the inside of which the pipe is wound; and as the vapor passes through the pipe, it is condensed by the lower temperature of the water within the vessel. Liquid substances give off vapor from their surface at temperatures below the boiling point, which is termed *evaporation*. It is called *spontaneous* evaporation when this takes place at the ordinary temperature of the atmosphere. A large quantity of vapor is given off from the surface of the earth and sea, which eventually forms clouds, or is condensed into rain and dew. Evaporation always produces cold when heat is not applied, the heat necessary for it being derived from the surrounding objects. A current of air, or a higher temperature, tends greatly

to quicken evaporation, as may be observed in the rapidity with which the surface of the earth dries when a brisk wind passes over it.

All substances become luminous when heated to 800 degrees in the dark, and 1000 in daylight, unless they are converted into vapor at a less elevated temperature. The light is at first red, and in this state the body is said to be in a state of *ignition*. If more heat is applied, the body becomes white, when it is said to be *incandescent*. When a body changes from the solid to the fluid state, a quantity of heat is absorbed which has no effect in raising the temperature. This is called *latent* heat. The same phenomenon takes place when a liquid is converted into vapor.

COMBUSTION is a process not yet perfectly understood. It is usually described as the union of a *combustible body* with a *supporter of combustion*, attended with the evolution of *light* and *heat*. The combustible body is that which burns, but in general will neither support combustion, nor burn, except in presence of a supporter of combustion. The supporter, again, does not itself burn, though necessary to the burning of a combustible. Oxygen gas, the ingredient which enables the air to support combustion, possesses, when pure, a high degree of the supporting quality. If a lighted taper, a combustible body, be plunged into this gas, the taper burns vividly, but the gas itself is not ignited. If, on the other hand, the taper be plunged into combustible gas, such as pure coal gas, the gas is instantly ignited, but the taper is extinguished. By examining the effects of combustion in the case of a candle burning in the atmosphere, it has been proved, pretty clearly,

that a chemical action of the following kind takes place: The combustible matter of the candle consists chiefly of two simple bodies, hydrogen gas and carbon, while oxygen is the supporter of combustion in the air. On burning a candle under a bell-shaped glass, filled with common air, a fluid gathers on the glass, which proves, on examination, to be pure water. The hydrogen of the burning body has here entered into combination with part of the oxygen of the air, forming water, a compound of the two. The carbon of the burning body also enters into union with a portion of the atmospheric oxygen, forming carbonic acid gas, which is left floating in place of the original quantity of oxygen. The same process takes place in the burning of coal, &c. Thus it seems that combustion only changes the forms of the burned bodies, and does not annihilate them.

Air, by the examinations of modern chemists, has been shown to be, not an element or a simple substance, but a compound body, consisting chiefly of two gases, oxygen and nitrogen. It also appears that the oxygen is the really active agent, in relation to animal respiration, and that the nitrogen is a mere diluent, in the mass, on the same principle as water may be made a diluent of spirits. Each individual is supposed, on an average, to breathe about twenty times in a minute; to take in about sixteen cubic inches of air at each inspiration; to return nearly the whole of the nitrogen and four fifths of the oxygen; and to replace the remaining fifth of oxygen by an equal volume of carbonic acid gas. The oxygen of the air is the great

means of procuring heat and light, by its action with combustible bodies.

WATER was also, at one period, believed to be a simple element in nature; but this supposition has given way before the examinations of chemists. Water is now known to be composed of oxygen and hydrogen gas, in the proportions of 8 of the former to 1 of the latter. Into these substances it can be resolved, by the action of electricity or fire. Sea-water contains, in 1000 parts, about 46 of foreign matters, chiefly chloride of sodium. Mineral waters, in a similar manner, contain various foreign bodies — as, for example, carbonated waters, which contain carbonic acid; sulphureous waters, which hold sulphureted hydrogen; and chalybeate waters, which contain sulphate or carbonate of iron. When water contains a chemical compound of lime, it is said to be *hard;* and, in this state, it decomposes the soap which is employed with it.

NITROGEN, or azote, is a gas permanently elastic, transparent, colorless, and inodorous. It is very little lighter than oxygen. When breathed, it destroys animal life; and a burning body, if immersed in a jar containing it, is instantly extinguished. United with oxygen in one proportion, it forms nitric acid, or aqua-fortis. Another compound of these two materials, in different proportions, constitutes the protoxide of azote, or, as it was formerly called, *nitrous oxide*, the inhalation of which causes a sort of temporary intoxication.

OXYGEN is a permanently elastic fluid, colorless, and destitute of taste or smell: combustible bodies burn in it with more brilliancy, and more light and heat are

evolved, than when combustion takes place in the atmosphere. HYDROGEN is also a permanently elastic fluid. It is the lightest body with which we are acquainted, and is employed, in combination with other gases, to inflate balloons. A bladder filled with this gas will ascend in the atmosphere in the same manner as a piece of cork plunged, to the bottom, will rise in water.

CHLORINE is a gaseous body of a yellowish green color, a strong, suffocating smell, and a very astringent taste. If breathed undiluted, it destroys animal life; yet it not only supports combustion, but possesses the remarkable quality of setting fire to many of the metals, even at the common temperature of the air, when they are beaten out into thin leaves and introduced into it. The combinations of metals with chlorine are called *chlorides*. Chlorine possesses the property of destroying all vegetable colors, and of rendering vegetable bodies exposed to its action white. This property renders it useful in bleaching: combined with hydrogen, it forms *muriatic acid*, which, united with oxides, produces an immense number of salts, such as common sea-salt, which is a muriate of soda.

CARBON, or charcoal, is found in many different forms, and can be prepared by burning wood, &c., in close vessels. The diamond is pure carbon; and plumbago, or black lead, is principally composed of this substance united with a little iron. It combines with all the supporters of combustion, and, with oxygen, forms carbonic acid. SULPHUR, or brimstone, we shall describe hereafter in the chapter upon minerals. When heated to 170 degrees, it becomes volatilized, and the

result is a fine powder denominated *flowers of sulphur*. Combined with oxygen, it forms *sulphuric acid*, or oil of vitriol.

PHOSPHORUS is chiefly prepared from bones, which consist mostly of the phosphate of lime. It is an amber-colored and semi-transparent solid, so very combustible that it takes fire in the air, emitting a white smoke having a smell of garlic. It also appears luminous in the dark.

Such is a brief description of some of the most important of the simple or elementary bodies which compose all known substances. Others we shall hereafter notice in the article on minerals. In a general summary, we may state that the simple bodies, or those which have never been decomposed, are fifty-four in number; and, for the convenience of study, they have been divided into metallic and non-metallic substances. The non-metallic elements are again divided into *gazolytes*, or bodies which are permanently gaseous; *metalloids*, or bodies which resemble the metals in their chemical relations; and *halogens*, or bodies which produce salts when in union with the metals. The non-metallic elements are thirteen in number,—namely, oxygen, hydrogen, nitrogen, chlorine, iodine, bromine, fluorine, boron, carbon, silicon, sulphur, selenium, and phosphorus. The first three are the gazolytes, the next four the halogens, and the remaining six the metalloids. The metallic elements are forty-one in number,—namely, potassium, sodium, lithium, calcium, barium, strontium, magnesium, aluminum, thorium, glucium, zirconium, yttrium, manganese, zinc, iron, tin, cadmium, cobalt, nickel, arsenic, chromium, vana-

dium, molybdenum, tungsten, columbium, antimony, uranium, cerium, bismuth, titanium, tellurium, copper, lead, mercury, silver, gold, platina, palladium, rhodium, osmium, and iridium. These metallic elements are again divided into three orders, — the first twelve being the bases of the alkalies and earths; the next twenty-one being metals whose oxides are not reduced by heat alone, and the remaining eight, whose oxides are reduced by a red heat.

From these fifty-four elementary substances are formed all the beautiful varieties of terrestrial objects: nor is there any thing very wonderful or mysterious in this fact; since, as we have seen, any given two of them, if made to unite in different proportions, are capable of producing the most opposite substances. Thus nitrogen and hydrogen, combined in certain proportions, form the vital air which we breathe; the same elements, combined in another proportion, produce an intoxicating gas; and again, in still another, produce *aqua-fortis*, which is a deadly poison. It is also to be observed that new substances, thus produced, united with each other, give rise to new compounds, which are susceptible of being combined, and so on through an almost infinite diversity of chemical union. From recent experiments in chemistry, however, it has been suggested that all substances whatever are but modifications of one primitive element; but the absolute truth of this startling theory remains to be practically demonstrated.

GEOLOGY.*

THIS science proposes to investigate the natural history of the earth — especially the general structure of what may be called its *crust*, or *shell*. It does not entirely overlook the internal strata, or even the nucleus, of our globe; but as these are beyond our inspection, it is possible to offer little more than speculations respecting them.

This noble science is of modern date. Certain theories had, indeed, been offered upon this subject;

* For a full view of this subject, see "Wonders of Geology."

but the extravagance of these, proceeding, as they often did, from men of the highest talent, affords humiliating lessons as to the absurdities in which the master-spirits of our race may be involved, when their footsteps do not follow the paths of experiment and observation. The great mathematician Kepler attempted to prove that the earth was a vast animal; the tides he regarded as occasioned by the heavings of its prodigious lungs. Plato and the Stoics seem to have entertained a similar opinion. Whiston, the English divine, considered the earth as produced by the condensation of a comet, and the deluge as occasioned by the visit of one of those erratic orbs.

Other theorists have ascribed the origin of the globe to fragments which have fallen successively from the heavens, in the form of aërolites. Our own Captain Symmes, of Cincinnati, seriously maintained that the earth was hollow, and inhabited, and that the interior was accessible by openings at the poles. He brought a vast deal of learning to the support of his theory, and even undertook to equip an expedition for the purpose of exploring the polar regions, in order to determine the question by observation. Perhaps, however, the palm of absurdity must be awarded to Voltaire, who accounted for the immense masses of sea-shells, found upon the mountains of Geneva, by supposing them to have been thrown there from the wallets of pilgrims in the holy wars! Such are some of the follies into which the highest intellect may be led, either by a partial observation of facts, or the adoption of a false philosophy.

The application of Lord Bacon's rule, which instructs

us to collect facts first, and form theories afterwards, has exploded the vain speculations of former geologists, and resulted in the establishment of the modern science upon a permanent and secure basis. The first person who pointed out the proper mode of investigation, in the pursuit of geological knowledge, was William Smith, a land surveyor, of Bath, England, who, in constructing roads and canals, observed that the same strata gave the same fossils, and that strata and fossils were always identical. This was a key; and no study ever became more popular, and raised itself into universal estimation more suddenly. Parkinson, Cuvier, Mantell, Brogniart, Sedgwick, Buckland, Murchison, Greenough, Lyell, Philips, Silliman, and the learned societies throughout Christendom, have been active in exploring this interesting field of knowledge.

NATURE OF THE CRUST OF THE EARTH.

The greatest thickness of the superficial crust of the globe — that is, of the mass of solid materials which the ingenuity of man has been able to examine, from the highest mountain-peaks to the greatest natural or artificial depths — is estimated at about 10 miles. As the earth is nearly 8000 miles in diameter, the entire series of strata hitherto explored is, therefore, but very insignificant, compared with the magnitude of the globe; bearing about the same relative proportion as the thickness of paper to an artificial sphere a foot in diameter; the inequalities and crevices in the varnish of such an instrument would be equal, in proportionate size, to the highest mountains and deepest valleys.

As a thickness of 100 miles so far exceeds that of

the whole of the strata that are accessible to human observation, we cannot doubt that disturbances of the earth's surface, even to ten times the depth of those which come within the scope of geological inquiry, may take place, without in any degree affecting the entire mass of the globe. If these facts be duly considered, the mind will be prepared to receive one of the most startling propositions in modern geology — namely, that the highest mountains have once been the bed of the sea, and have been raised to their present situations by subterranean agency, — some slowly, others suddenly; but all, geologically speaking, at a comparatively recent period.

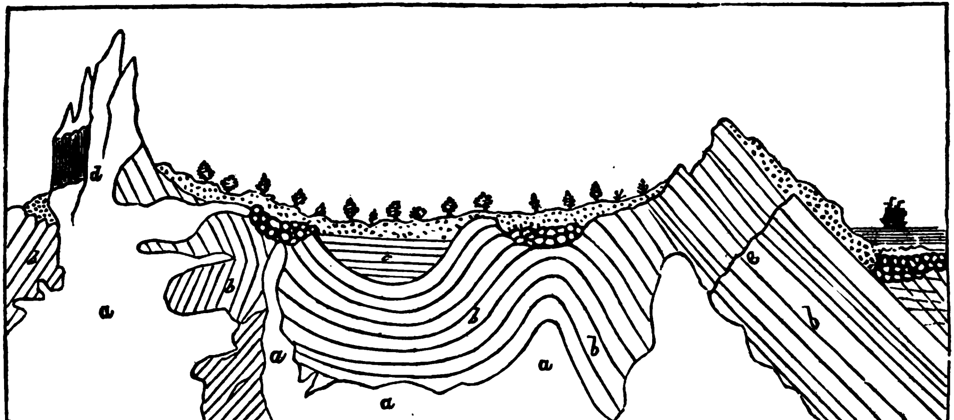
The superficial crust of the globe is composed of numerous layers and masses of earthy substances, of which, combinations of iron, lime, and silex, or flint, constitute a large proportion; the latter forming 45 per cent. of the whole. Those strata which have been deposited the latest, bear evident marks of mechanical origin, and are the water-worn ruins of older rocks; as we descend, materials of a denser character appear, which also exhibit proofs of having been subject to the action of water; but when we arrive at the lowermost in the scale, a crystalline structure generally prevails; and while, in the newer strata, trees, plants, shells, and other remains of animals and vegetables, are found in profusion, in the most ancient rocks all traces of organic forms are absent.

CLASSIFICATION OF ROCKS.

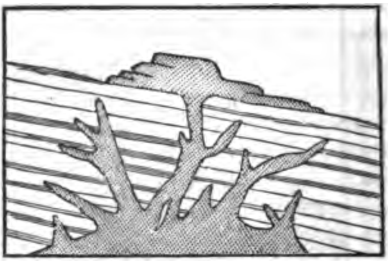
In casting a casual glance over the broken and diversified surface of the globe, its materials might present

a scene of utter confusion; but the scientific observer, by investigation and comparison, is able to make out certain analogies which become the foundation of scientific arrangement. Thus geologists class all the rocks which form the crust of our globe into two grand divisions—viz., the *unstratified* and the *stratified*. The former are supposed to have been formed by the action of fire, and have, therefore, been called *igneous*. These are entirely destitute of organic remains. The latter are disposed in beds or strata, and, being supposed to derive their present arrangement from the action of water, are called *aqueous*. Among these are found the fossil remains of plants and animals. The *igneous* or unstratified rocks form an extensive group, of which granite and lavas occupy a prominent part. Porphyry, diallage, pitchstone, basalt, scoriæ, and the trap-rocks, belong to the same series. All these substances possess evidences of a common origin, and exhibit the same geological phenomena. Their relative ages, in respect to each other, we have no means of determining. But there are certain rules by which we may ascertain, in particular circumstances, their relative antiquity, as compared with adjacent rocks. For example, if we find a mass of granite penetrating a particular stratum, breaking it up, and branching through it in veins, we must conclude that here the granite is the more recent of the two; that it assumed its present position subsequently to the formation of the stratum which it traverses.

The figure at p. 272 represents granitic veins, branching through stratified rocks, and overlaying them at the surface. The proofs of the igneous origin of the un-



a Primary Rock, which has been thrown up, so as to disturb and mix itself with the Secondary Rocks.
b Secondary Rocks, thrown into inclinations and curves by the rising of the Primary Rocks.
c Tertiary Formation, deposited in a hollow formed by the disturbance of the Secondary Rocks.
d Basaltic Columns. *e* A fault or hitch in the strata.
The circles are Boulders or detached stones, rounded by travelling in water, and deposited in hollows formed by water. The dots indicate beds of gravel immediately beneath the soil.



Granitic Veins piercing through Strata.

stratified rocks are very complete: not only does their structure establish it, but we find that, wherever they have been erupted into, or through, the stratified rocks, the texture of the latter, at the point of contact, exhibits the marks of the action of intense heat. Thus, wherever the slate-rocks are intersected by granitic veins, they assume the appearance of mica-slate, or hornblende; beds of shale and sandstone are reduced to jasper, and compact limestone and chalk are converted into crystalline marble.

The stratified rocks have been classed under the four following divisions: —

1. The *primary*, consisting of gneiss, quartz, hornblende, &c., but containing no organic remains.

2. The *transition*, presenting alternations of slate and shale, with slaty sandstone, limestone, and conglomerate rocks, and containing remains of fishes, shells, and vegetables. The coal-formation belongs to this division.

3. The *secondary*, which include the lias and oölite formations, various limestones, variegated sandstone,

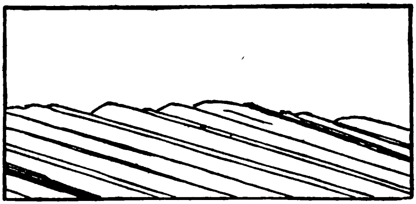
conglomerates, and others. They are richer in organic remains than the transition rocks. We here find the remains of gigantic lizards, of the most extraordinary description, with turtles, opossums, and kangaroos, and various kinds of trees and plants.

4. The *tertiary* rocks, consisting chiefly of alternating strata of marine and fresh-water deposits, and containing in great abundance the remains of animals and plants, approaching, in genus or species, to those which at present inhabit our continents and seas.

ARRANGEMENT OF STRATA.

The igneous and primary rocks constitute, mainly, the hills of New England, and the mountain group in the northern part of New York; also the Blue Ridge and its collateral elevations, extending south-westerly through the Atlantic states. The transition and secondary rocks constitute the greatest portion of the interior of the United States, west of New England. The tertiary deposits form a large portion of the shores and low country of the states south of New England, and bordering on the Gulf of Mexico.

Strata are generally inclined at greater or less angles to the horizon; and their ends or edges *crop out*, at the surface, from under each other: were the arrangement otherwise, we should have remained forever in ignorance of many of the lower rocks, because we could only have reached them by cutting through enormous superincumbent masses, of impenetrable thickness; coal, for example, would have been unknown to us, and also the metals in which the inferior



Strata cropping out.

strata abound. But, in consequence of the admirable arrangement of nature, we obtain easy access to all the different districts.

As we walk over a country, we perhaps come upon the *out-crop* of primitive rocks; and here, though dreary and barren, the country is wild and romantic, and affords valuable minerals. We advance upon more recent formations, where we have no minerals, but where we find a district rich in agricultural produce. Farther on, it may be, we come to strata abounding in coal, and affording scope for the exercise of manufacturing industry.

Strata are not only elevated at various angles, but we often find them twisted and contorted in divers forms, according as they have been acted upon by the igneous agents which disturbed their original tranquillity.

AGE OF ROCKS.

The relative antiquity of stratified rocks is determined by the order in which they lie upon each other, and by the organic remains of animals and plants imbedded in them. Thus the aqueous deposits of the present period, those which we see forming under our

own eyes, and which enclose the remains of vegetables scarcely altered, and of animals still living on the surface of the globe, are the uppermost of all the others. Immediately below these comes the *diluvium*, of the nature of which little is known. Continuing to descend, we meet with rocks, the remains enclosed in which differ, more and more, from those of our day. At last, we arrive at the crystalline stratified groups; the oldest of two rocks being always that which is lowest. These different groups, again, are subdivided into formations; and, independently of superposition, we judge of their relative ages, and of the length of time which must have elapsed between them, by the fossils peculiar to each.

Let us take the tertiary rocks, for example. This series has been arranged under four chronological divisions. In the oldest, out of 1200 shells found in the strata, not 50 belong to existing species. In the second, out of 1000, we have about 170 still surviving. In the next, from a half to a third of the shells now exist; and in the fourth, or more recent, almost all the imbedded shells belong to species still living in our seas. In Sicily, portions of the last-mentioned, or *newest* formations, rise to the height of 2000 feet, and contain shells and corals which are at present found in the Mediterranean.

FORMATION OF ROCKS AND STRATA.

Among the recent formations, *peat* is one of the most curious. It is formed of decomposed vegetables, and is supposed to be the origin of coal. Forests which have been overthrown by storms, instances of which have been frequent, contribute to the formation

of peat. The decay of the leaves and small branches commences the process, and the interstices are gradually filled up, until the trunks are enclosed and covered. Hence the frequent occurrence of the remains of trees, both in the peat and coal formations. These trees are sometimes so numerous as to form, in fact, fossil forests. In the valley of the Saome, a mass of peat reposes on an immense quantity of the branches and trunks of the dycotylenous trees heaped on each other, and resting on clay. On the borders of the Rhine, there exist similar masses, in which the trunks are so flattened, that trees of a foot in diameter present a thickness of only two inches.

Of the vegetable origin of coal there can be no question. In order to account for the formation of the immense beds of this useful mineral which are found, we may suppose that vast masses of peat have been formed by a vigorous and luxuriant vegetation, created by heat and moisture. These, by some convulsions of the surface of the earth, have been sunk beneath superincumbent layers of earth or water, and thus subjected to great pressure. In this position, in the course of ages, and probably by the aid of great heat, they have been converted into beds of coal. These are found in all climates — in India, Europe, America, New Holland, and Greenland.

Various beds of *sandstone* are found to exist amid the stratified rocks. These have been produced by the decomposition of older rocks. The evidences of this are abundant. The old red sandstone, for example, is composed of quartz, feldspar, and mica. In the more recent sandstone, fossil remains of trees and

plants are very common. The interior of the plant is usually filled up with sand, while the bark is converted into coal. Shells, encrinites, and other fossils, are also found in this formation. The new red sandstone is found in New Jersey, and along the banks of Connecticut River, and constitutes a building material much in use.

Limestone formation composes nearly one eighth part of the crust of the globe. The recent limestone is produced partly by the secretions of shells and corallines, and partly from the decomposition of ancient limestone rock. Whence the latter has been derived is not yet determined, though it is probable that this also is formed of coral, shells, and other marine substances. The mountain limestone contains many crevices, and sometimes vast caverns hung with stalactites, which, seen by torchlight, present spectacles rivalling the scenes presented in the tales of enchantment.

Coral reefs are among the most interesting phenomena in geology. Vast islands in the midst of the ocean, reaching to the bottom of the almost fathomless deep, and spreading out for hundreds of miles upon the surface, belong to this class; but the most curious circumstance is, that they are the production of animalcules scarcely visible to the naked eye. It is wonderful to reflect that the structures of these minute creatures surpass in magnitude, by a thousand fold, all the works of mankind from the creation to the present day. The manner in which the corallines work is curious, and seems to evince something that approaches intelligence. Having once raised their structure above the water, so as to serve for a wall, to breast the waves,

they proceed to the leeward side, where they can work in quiet, undisturbed by the agitation of the sea.

When the mass has been formed to some extent, the action of water and the atmosphere decomposes the surface, and furnishes an alluvial soil. Seeds of plants are borne thither by the waters and the wind, and vegetation begins. Birds resort to it; the eggs of insects are carried thither; and man, at last, comes and forms a settlement: such is the history of most islands. Some of them, disturbed by volcanic action, present peaks and cliffs 200 or 300 feet in height. The wonderful labors of the zoophites have been commemorated in the following lines by Mrs. Sigourney:—

Toil on! toil on! ye ephemeral train,
Who build in the tossing and treacherous main;
Toil on;—for the wisdom of man ye mock,
With your sand-based structures and domes of rock:
Your columns the fathomless fountains lave,
And your arches spring up to the crested wave;
Ye're a puny race, thus boldly to rear
A fabric so vast, in a realm so drear.

Ye bind the deep with your secret zone;
The ocean is sealed, and the surge a stone;
Fresh wreaths from the coral pavement spring,
Like the terraced pride of Assyria's king;
The turf looks green, where the breakers rolled;
O'er the whirlpool ripens the rind of gold;
The sea-snatched isle is the home of men,
And mountains exult where the wave hath been.

But why do ye plant, 'neath the billows dark,
The wrecking reef for the gallant bark?
There are snares enough on the tented field:
'Mid the blossomed sweets that the valleys yield,

There are serpents to coil ere the flowers are up;
There's a poison-drop in man's purest cup:
There are foes that watch for his cradle breath, —
And why need ye sow the floods with death?

With mouldering bones the deeps are white,
From the ice-clad pole to the tropics bright;
The mermaid hath twisted her fingers cold
With the mesh of the sea-boy's curls of gold,
And the gods of the ocean have frowned to see
The mariner's bed in their halls of glee.
Hath earth no graves, that ye must spread
The boundless sea for the thronging dead?

Ye build — ye build — but ye enter not in,
Like the tribe whom the desert devoured in their sin:
From the land of promise, ye fade and die
Ere its verdure gleams forth on your weary eye;
As the kings of the cloud-crowned pyramid, —
Their noteless bones in oblivion hid, —
Ye slumber unwaked 'mid the desolate main,
While the wonder and pride of your works remain.

Chalk, which is found in vast beds, appears to have been entirely composed of masses of marine shells gradually consolidated, with a little intermixture of foreign matter. It is common in England and France, but none has yet been found in America. Rock-salt is an extensive formation, but its origin has not been satisfactorily explained. The strata, both above and below it, have been found to contain organic remains.

Diluvium consists of those beds of gravel, clay, and sand, which we find on the surface of the upper strata. They are not usually stratified, and contain immense numbers of rounded stones, some of great size and weight. These comprehend specimens of various

rocks, such as mica-slate, granite, trap, sandstone, ironstone, and many others. These have evidently been subjected to the action of water, by which they have been rolled against each other till they have assumed their present smooth and rounded appearance. They are often found in elevated situations, having been brought hither by vast currents of water in some convulsion of nature which upheaved the surface of the earth.

Alluvial soil is to be distinguished from diluvium; the former consisting of those recent masses of earth which are carried down by rains and floods, and deposited in valleys along the banks of lakes and rivers.

Erratic blocks, or boulders, are those enormous masses of granite, and other stones, which are found often at a great distance from any beds of similar formation. They lie scattered over the plains, and even on the elevated sites of mountains, in many countries. It would appear that some of these, weighing many tons, have been torn from their original resting-place, and carried to a distance of hundreds of miles. Similar blocks of granite have been found in Iceland, which is entirely composed of lava; and the nearest point from which they have been transported, would seem to be either Sweden or Norway — the German Ocean intervening between these countries and Iceland. It is supposed that these blocks have been transported in icebergs at a period when the ocean swept over the countries where they were originally formed, and where they now are found.

FOSSIL REMAINS.

No department of geology is more attractive than this. It seems to open a new volume of the world's history, and to unfold the archives which have been sealed in oblivion for ages. It is impossible, in the present sketch, to present more than a brief outline of this interesting topic. It must be sufficient to say, that the vestiges of trees, plants, and shrubs; of insects, birds, fishes, and quadrupeds; are found imbedded in the strata of the earth: and, what is most wonderful, these are, for the most part, of species now extinct. It must be added, that the remains of animals and vegetables are found in climates repugnant to their nature; as, for instance, those of plants and animals fitted only to the tropics are found abundantly even along the margin of the Arctic Sea.

Among the fossil animals are the *dinotherium*, an herbivorous quadruped, 18 feet in length, and holding an intermediate place between the tapir and the mastodon; the *megatherium*, of the sloth species, covered with a bony coat of armor, like the armadillo, and exceeding the rhinoceros in bulk; the *ichthyosaurus*, or fish lizard, resembling the porpoise, and sometimes 30 feet in length; the *plesiosaurus*, having the head of a lizard, the teeth of a crocodile, the tail of a quadruped, ribs like those of the chamelion, paddles like a whale, and the neck of a serpent; the *pterodactyle*, with a neck like a bird, wings like a bat, and a body like a lizard; and the *iguanadou*, an enormous lizard, sometimes 70 feet in length.

These are the remains of some of the wonderful

animals found in the more ancient strata. Among the more recent formations, are the remains of the mammoth and mastodon; birds resembling the woodcock, quail, cormorant, owl, and buzzard; fishes of a thousand forms; and shells in countless abundance, and of infinitely diversified forms.

CHANGES OF THE EARTH'S SURFACE.

No principle, in geology, is better ascertained by facts, than that many successive destructions and renovations have taken place on the surface of our globe. We are apt to imagine that all the great revolutions of the earth have been sudden and violent, and some of these have doubtless been so; an instance of this kind is that recorded by Moses, and which, in consideration of the great revolution which was effected, and the new aspect which the world presented, is properly spoken of as a *creation*. But, in general, we have reason to believe that the mutations and revolutions which have been wrought upon the globe, for a series of ages, have been the work of great and powerful agents still in operation, and still accomplishing their destined task of change and revolution.

There are two great antagonist powers in nature — the *aqueous* and *igneous*. These are visible, and in operation, at the present hour. The former, as in springs, rivers, tides, frosts, and rain, is constantly employed in the disintegration of rocks, and in the degradation, or levelling, of land. The latter, by volcanoes and earthquakes, is, on the other hand, employed in restoring the elevation and inequalities of the surface. Were there no such compensating power of

elevation, a time would come when the whole materials of the loftiest mountains would be transported to the ocean, and when the whole earth would be reduced to a saline marsh.

Among the aqueous instruments of change, we may notice rain, which is constantly at work in dissolving the hardest substances, and carrying them down from elevated to lower situations. This operates on a mighty scale, and is sufficient to account for the formation of some of the great valleys of the earth. The ocean, by constant attacks upon its coasts, gradually fritters away the rocks, and has been known to destroy large tracts of country by forcing its waters into the interior of continents; numerous instances of such irruptions are on record. But while the sea is thus a powerful agent of destruction, it is, like the rivers, instrumental in the reproduction of land. The rocks and sand washed away from one place are carried, by tides and currents, far into the ocean, where they are deposited in strata, and in course of time form shoals and banks, which afterwards become promontories and islands. Marine currents are numerous, and tortuous in their course; and, like rivers, carry in suspension abundance of mineral matter, which they deposit at different places. Hence, in inland seas, and even on the borders of the ocean, it is sometimes scarcely possible to prevent a harbor from filling up.

Among the igneous causes of change in the earth's surface, are *volcanoes* and *earthquakes*, which are inseparably connected, and result from the same causes. The former are chiefly confined to certain geographical limits; some are periodical, while others are in a state

of constant activity. Stromboli, in one of the Lipari Isles, has never ceased its action during a period of more than 2000 years; while Vesuvius and Etna give forth eruptions only at intervals, and others have been dormant for ages.

In the snowy regions of the Andes, the effects of an eruption are terrific; for not only are torrents of lava ejected, but the intense heat melts the snow, which causes inundations, carrying the volcanic sand, stones, and rocks, down with desolating fury upon the plains below. Iceland is entirely of volcanic origin; and so intense has been the volcanic action, that Hecla has sometimes continued in a constant state of eruption for six years, shaking the whole island, and causing great changes in its surface. In 1783, another volcanic mountain in Iceland, called Skaptartoyul, burst forth, and, throwing out a torrent of lava into an adjacent river, completely dried it up. Not only did the lava fill the channel, which was 600 feet deep and 200 wide, but it overflowed the neighboring fields; filled up an extensive lake; and, advancing against an ancient mass of lava, melted it down—blowing up large fragments of rocks, in its progress, to the height of 150 feet: not yet arrested, it continued its terrific course, filled the deep abyss which the great waterfall of Steppafoss had been hollowing out for ages, and then spread in various directions, carrying ruin and destruction over the country. Of the two streams of lava which flowed from the mountain in opposite directions, one was 40, and the other 50, miles in length; the breadth varied from 7 to 15 miles, while the ordinary height of both

currents was 100 feet, though, in narrow defiles, it sometimes amounted to 600.

This awful eruption continued two years; and a traveller, who visited the tract eleven years afterwards, found columns of smoke still rising from parts of the lava, and several rents filled with hot water. No fewer than twenty villages were destroyed on this occasion; and more than 9000 of the inhabitants perished.

The amazing effects of volcanoes almost surpass conception; mountains of great height have been thrown up in a single day, and have taken their rank among the permanent elevations of the globe. In 1759, Jorullo, in Mexico, was elevated, in the space of two months, into several cones — the central one being 1600 feet above the level of the plain. Forty years afterwards, when Humboldt visited the place, he found the mighty masses of lava still so hot, that he was able to light his cigar at the depth of a few inches. Two small streams, which had disappeared during the eruption, afterwards burst forth as hot springs in a position remote from their former course. Such is the expulsive power of volcanoes, that Cotopaxi has been known to project rocks, more than 100 tons in weight, to the distance of nine miles.

Nor are volcanoes confined to the land; they sometimes burst forth from the middle of the sea, displacing the waters, and rearing up islands to the height of 100 feet.

Earthquakes are remarkable for the extent of country over which they operate. The shock of an earthquake in Chili, in 1822, was simultaneously felt throughout a space of 1200 miles, from north to south.

During the convulsions of an earthquake, the surface of the earth undulates like a boiling liquid; the sea heaves and swells as in a tempest; edifices are thrown into heaps of ruins, and enormous fragments of rocks are detached from the mountains. In some instances, whole cities have been ingulfed in the space of a few minutes; and extensive districts of country, teeming with wealth and prosperity, have been suddenly converted into ghastly spectacles of desolation.

The explanation of these sublime, yet terrific phenomena, is to be found in the action of heat, generated by chemical causes in the bowels of the earth. When this has melted vast masses of rock into a flood of lava, the boiling flood seeks vent, and, in its egress, rends every thing asunder which obstructs its path. There is reason to believe that every portion of the earth has been at successive periods covered by water, and that the present elevations, even including the Andes and the Alps, have been upheaved from the bottom of the sea.

MISCELLANEOUS TOPICS.

The difference between the former and the present temperature of northern latitudes, is a highly interesting topic in geology. It is a fact fully admitted that the climate of the northern hemisphere was once much hotter than it is at present. Fossil plants, and animals, analogous to species which only subsist, at present, in tropical countries, are found strewed over the northern parts of Europe. To account for the change of climate thus indicated, various theories have been suggested; but the most probable one is, that the ocean

and land had once a different arrangement from the existing one, and that, at a former period, currents flowing from the tropical regions, and other circumstances tending to the same point, contributed to soften the temperature of those regions which have since become frigid. Various attempts have been made to account for the deluge upon geological principles. It has been suggested that an elevation of the bottom of the sea, with a corresponding depression of the mountains, making nearly a level surface over the earth, enabled the accumulated waters to spread over the whole extent of the globe. But this supposition appears inconsistent with the language of Scripture. This implies a vast increase of the waters upon the earth: as we cannot assign any natural cause for this, we must refer it to the miraculous agency of that mighty Being whose stupendous operations sink into comparative insignificance the entire creation of a globe like ours.

The *age of the earth*, deduced from the archives of nature, as recorded in the rocks of the earth's surface, has been supposed to be millions of years. This has been thought to impugn the veracity of the Mosaic history, which seems to represent our globe as having been created about 6000 or 7000 years ago. A proper reading of the Bible, however, shows no incompatibility with the facts attested by geology. The six days spoken of in Genesis, during which the work of creation was performed, may have been six indefinite periods of time, each millions of years in length; or, what is more probable, the six days were of the ordinary length; but, previously to the first day, a vast

period of time had elapsed, during which all those strata were formed, and those plants and animals lived, the existence of which, previously to our own epoch, is so clearly proved. In this view, the Mosaic creation is to be regarded as a renovation of animal and vegetable life, and a preparation for the reception of man. That such a work was actually performed upon this globe, at the period indicated by the Scriptures, is as clearly demonstrated by geology as by holy writ; for, while we find the vestiges of other races of plants and animals, that lived ages ago, we find no traces of man himself which indicate his existence at a period earlier than that which the Bible establishes.

MINERALOGY.

THE object of this science is, to describe the general composition, characters, varieties, forms, and combinations, of mineral bodies. A mineral may be described as a substance destitute of organization and vitality, found on the surface of the earth, or imbedded at various depths beneath it, in veins, or strata, which are worked for the extraction of such substances, by excavations called *mines*.

Mineralogy may be distinguished from chemistry, as relating to the forms and properties of certain bodies as they are presented to us by nature; while the latter science instructs us how to procure a multitude of

artificial products derived alike from the animal, vegetable, and mineral kingdom, and to expose their properties, especially as respects their rule of combination.

Mineralogy is likewise to be distinguished from geology, with which, however, it is intimately connected. It is the province of the geologist to investigate the general structure of the earth, and the nature and arrangement of the great masses of which it is composed. The mineralogist, on the other hand, confines his attention to individual portions of unorganized matter, distinguished by peculiar and specific characters.

In the study of geology, it is of the utmost importance to be enabled to examine the objects of research, as they are formed by nature, and to ascertain their relative connection and arrangement in the formation of rocks, mountains, plains, subterraneous strata, and, in general, of all the great masses the assemblage of which constitutes the solid shell, or exterior surface, of the terrestrial globe. The nature and properties of minerals may be investigated and ascertained, without any reference to the situations in which they are produced.

Thus connected as mineralogy is with chemistry on the one hand, and with geology on the other, it displays features sufficiently distinct from those of either; yet, at the same time, the objects of these sciences so far correspond that a complete knowledge of mineralogy cannot be obtained without a previous acquaintance with chemistry; nor can the information which these sciences form, when united, relative to the unorganized productions of nature, be applied to a more

exalted purpose than that of aiding our researches concerning geology.

Mineral substances may be discriminated from each other by their mode of crystallization or aggregation; and the optical properties depending upon their peculiar forms, by their physical characters, as *color*, *lustre*, *transparency*, *hardness*, *consistency*, *density*, or *specific gravity*; as also, in some cases, by their *taste* or *odor*, by their *relations to electro-magnetism*, and finally by their *chemical constitution*. The manner in which the particles of minerals are arranged, or their *crystallization*, is a curious and interesting subject of inquiry. Any or all of these various qualities and affections may be taken into consideration in forming classical arrangements of bodies belonging to the mineral kingdom of nature. Hence a diversity of systems and arrangements have been contrived by various mineralogical writers. In general, we regard the mineral kingdom as divided into four departments—*earths*, *metals*, *salts*, and *combustibles*.

Within the narrow limits of this sketch, we have room only to mention a few of the most important mineral bodies. One of these is lime: this is never found pure, but is obtained artificially by burning limestone till the carbonic acid which it contains is driven off. Limestone is of various kinds, the hardest of which is marble. Lime enters into the composition of a number of earthy or stony minerals, and exists in such abundance, that some geologists have estimated that it exists, in the crust of the globe, in the proportion of one eighth of the whole. This substance, and its compounds, are of infinite importance and utility to man.

Chalk is a carbonate of lime, but is far less abundant than compact limestone; it contains flints and animal remains.

Coal has been generally ranked among minerals because its basis is pure carbon; but it is generally supposed to be of vegetable origin, as the substance which lies upon the coal is always filled with vegetable remains, and a wood-like appearance may be traced through every species of coal, even the most compact. The harder species, which burns without smoke, is called *anthracite*. There are few countries in which coal is not found more or less abundantly. England is remarkable for its coal mines. In the United States, it is most abundant in Pennsylvania.

Mineral salt is found in beds or masses. It is not a simple substance, but is composed of earth, soda, and muriatic acid. It is one of the most plentiful substances in nature, being not only dug out of the earth, but forming a thirteenth part of the waters of the ocean. Salt or brine springs are found in many countries, affording immense quantities of salt by artificial evaporation. Rock-salt is sometimes found on the tops of mountains, far above the region of perpetual snow. In Hungary and Poland, there is an immense body of rock-salt at the foot of the Carpathian Mountains. The salt mine of Wieliczka, near Cracow, in Poland, has been worked since the year 1251: the salt commences about 200 feet below the soil, and the mine has been wrought to the depth of 900 feet. The galleries are completely dry, and the mine contains springs of both fresh and salt water. In this mine are several chapels for the workmen, some of which are

furnished with altars, crucifixes, and statues, all of solid salt. In Moldavia is a mountain of salt, which in many parts is not covered even with soil. The annual production of salt, in England, has been estimated at 500,000 tons.

Sulphur is a primitive substance, and takes its rank among the combustibles. It is found not only in the mineral kingdom, but in the vegetable and animal; though, in the two latter, it occurs so rarely, that all the vast commercial demands for it are supplied from the former source. It is found nearly pure, and is then termed *native sulphur*. It is also found in combination with several of the metals; and, in the state of an acid, it occurs combined with some of the earths and metals. It is sometimes, though rarely, found in veins in primitive mountains: its common repository is in beds of gypsum, where it appears in rounded masses. Volcanoes abound with sulphur, which is thrown up in the rifts and cavities of the lava in the neighborhood of their craters. Volcanic sulphur is found in Italy, Iceland, and America, in volcanoes yet in activity. The volcanoes of the Cordilleras, in Quito, yield it in great abundance, and very pure. But the most remarkable deposit of volcanic sulphur is that of Solfatara, near Naples, in a kind of sunken plain, surrounded by rocks, which is regarded as the crater of an ancient volcano; and from this place, ever since the age of Pliny, has been obtained a considerable portion of the sulphur consumed in Europe. The uses of this substance in chemistry, medicine, and the arts, are important, and sufficiently well known.

The diamond may be classed in the same rank with

sulphur, being a combustible, and not, as was formerly believed, an earthy or stony substance. When exposed to a current of air, and heated to the temperature of melted copper, it is found to be gradually, but completely, inflammable. By this process it may be wholly converted into carbonic acid, and therefore consists of pure carbon. Diamonds are either colorless, or yellow, blue, green, brown, or rose-red. They are always found in detached crystals, and, in their primitive form, are eight-sided. Although the diamond is the hardest substance in nature, it may be readily cleaved in particular directions. It may also be worn out by long use and continual friction. In the shops of wholesale glaziers, where it is in constant requisition for the purpose of cutting glass, it is often rendered useless in the space of two months. It may be presumed, however, that it travels over many miles of glass, before it is worn too smooth for use.

Diamonds can be cut and polished only by friction against each other, or rather by means of their own powder. They are sometimes sawed by a delicate iron wire, coated by their own powder. This art was unknown till the year 1486, and of course the ancients could not have been acquainted with the great brilliancy of the diamond, as this, in a great degree, depends on the art of the lapidary. Its uses are well known; its value increases in a much greater ratio than its weight. The largest known is about the size of a pigeon's egg, and was formerly possessed by the empress of Russia. It is said to have been sold for 416,666 dollars, and a pension of 16,666 dollars for life. India and Brazil are almost the only countries known to afford this precious stone.

METALS next claim our attention. These are simple substances, not one of them yet having been decomposed. In weight, the metals far exceed the earths; the heaviest of the latter is only five times heavier than water, while the lightest of the metals is six times heavier. Beaten gold is nineteen times heavier, and beaten platina, the heaviest of all, is twenty-three times heavier than water. Each metal possesses a color peculiar to itself. Some of them are exceedingly ductile, as is manifested by the extremely fine wires into which they are drawn. Most of them are good conductors of electricity and heat, and the greater number are elastic and flexible.

The only metals known to the ancients were gold, silver, copper, iron, tin, lead, and mercury; but discoveries have, from time to time, added to the catalogue until it has been swelled to the number of twenty-eight, independently of those which have very lately been discovered as the bases of some of the earths and two of the alkalies. Of these twenty-eight metals, eleven only have the important property of malleability; the remainder therefore have been termed *brittle* metals. The malleable metals are platina, gold, silver, mercury, lead, copper, tin, iron, zinc, palladium, and nickel. The brittle metals are arsenic, antimony, bismuth, cobalt, manganese, tellurium, titanium, tantalium, molybdena, tungsten, chrome, osmium, iridium, rhodium, uranium, and cerium.

Gold was probably the first metal that attracted the notice of mankind, and was applied to purposes of utility or ornament. As it is not rusted or decomposed by air or moisture, it preserves its metallic lustre, and

is generally found, in its metallic state, nearly pure. The ductility of gold, and its easy fusibility, were properties that enabled the first rude artificers to mould it with facility into various forms, and contributed, no doubt, to stamp a high value on this metal in early ages — a value which it has retained, from its imperishable nature and comparative rarity. It is probable that gold, silver, and afterwards copper, were for a long time the only metals used by mankind, as they are the only ones that occur in any considerable quantities in a native state, or near the surface of the earth. Hence, perhaps, originated the tradition of the golden, the silver, and the brazen ages. Though gold is less abundant than many other metals, it is distributed over almost every part of the known world, either in veins, or disseminated through the sands of rivers or alluvial soil, in loose grains and detached masses. The gold collected by washing the sand of rivers is called *gold dust*. In malleability, it is superior to all other metals; a single grain of gold will cover the space of 56 square inches, when beaten out to its full extent; yet the tenacity of this metal is so great, that a wire one tenth of an inch in diameter will hold a weight of 500 pounds without breaking. When used for mechanical purposes, or for coin, it is alloyed with silver or copper, to increase its hardness.

Platina, the heaviest of all known substances, is of a grayish-white color, approaching that of silver, but with less lustre. It is somewhat inferior, in hardness, to iron. The hottest furnace cannot melt it, though it may be fused in the focus of a powerful mirror, or by a blowpipe with oxygen gas. It does not oxidate in

the air, or a strong heat; and its hardness, infusibility, and resistance to those elements, indicate the important uses to which it may be applied. Thus it is employed for crucibles, spoons, evaporating vessels, pendulums, pyrometers, &c. It is found in grains, in alluvial soil, in South America; the grains are commonly no larger than a pea, although masses have occurred of the size of a pigeon's egg.

Silver, when pure, is very nearly white. In lustre it is superior to gold, but in malleability somewhat inferior. It is not oxidated by exposure to the air, but only acquires a tarnish. The ores of silver are more numerous than those of gold, and they occur principally in veins, in mountainous districts; sometimes at great elevations. The mine of Jauricocha, in Peru, is about 3 miles above the sea, and contains a prodigious mass of porous, brown iron-stone, half a mile square and 100 feet deep, thoroughly interspersed with pure silver. The mines in this quarter have yielded 40,000,000 dollars in a year. Native silver is found, in considerable masses, in some mining districts that contain silver ores; in others it occurs rarely, and in small quantities. Koningsberg, in Norway, has furnished the largest solid masses of native silver, some of which have exceeded 200 pounds in weight. When it is coined, it is alloyed with copper.

Mercury, or quicksilver, differs remarkably from all other metals, by its fluidity. It is thirteen times heavier than water; and iron will float in it. It becomes solid at 40 degrees below zero of Fahrenheit; and in this state it is malleable and flexible. Mercury is found native, but most generally in combination with other minerals.

When combined with sulphur, it is called *cinnabar*, which is the red pigment otherwise known as *vermilion*. The ores of mercury are not widely distributed over the globe: almost the only mines known are those of Idria in Germany, Almoden in Spain, and Guanca Velica in Peru. The uses of this metal, in medicine, the arts, and experimental philosophy, are numerous; but its chief use is in the separation of gold and silver from their ores, by a process called *amalgamation*. When mercury is amalgamated with tin, and laid on glass, it forms mirrors.

Copper, before the general introduction of iron, appears to have been used for almost every purpose to which the latter metal has since been applied. It was made into swords and other edge tools; a considerable degree of hardness being communicated to it by an alloy of tin. Native copper is of a yellow-red color, and is often found nearly pure, in large masses, on the surface of the earth. This was probably the cause of its being brought into early use; it is obtained from most of its ores with considerable difficulty. These ores are numerous. The uses of copper in all its various states are almost endless, and only inferior to those of iron. Alloyed with certain proportions of zinc, it forms brass, pinchbeck, tinsel, and Dutch gold, in imitation of gold-leaf. With a small proportion of tin, it forms bell-metal, and bronze for statues and cannon; with a larger proportion, it forms speculum-metal for reflecting-telescopes.

Tin is the lightest of the ductile metals. It is of a white color, nearly approaching to that of silver. It is easily fusible, and produces a peculiar cracking noise

when bent. It has not hitherto been found in a native state, and its ores are not widely distributed over the globe. The uses of tin are numerous and important. Some of them have been already specified. With lead it forms pewter, and solder. It is employed in the preparation of tin-plate, which consists of sheet-iron tinned over, to prevent rusting. It is also applied to the inner surface of copper vessels designed for cooking, to prevent the injurious effects arising from the copper. The chief mines of this metal are those of Cornwall, in England, and Banca, in the East Indies.

Lead is of a bluish-gray color, and is very malleable, ductile, inelastic, and soft. It has hardly ever been found native, but its ores are numerous. The almost constant occurrence of silver with lead, seems to indicate that these metals have a common origin. By friction, this metal exhales a peculiar and somewhat disagreeable odor. It would scarcely be possible to enumerate all the valuable purposes to which lead is applied in the arts, in medicine, and in the common wants of man. Among its less obvious uses, lead is employed to glaze pottery, and its oxide enters into the composition of glass. Four parts of lead and one of antimony, with a little copper, form type-metal.

Iron is an ingredient in almost every rock, from the oldest primitive to the newest alluvium, and also in very many earthy and metalliferous minerals, and in all soils; it is, therefore, considered to be the most abundant and most generally diffused of all the metals. Whenever found, and with whatever combined, it is mostly in the state of an oxide, except when united with sulphur.

When pure, it is of a bluish-gray color, and of a granular texture; it is hard, ductile, and malleable, and is the most tenacious of metals, next to gold. It has the remarkable property of being magnetic; and so readily is polarity acquired by iron, that a bar remaining a long time in a vertical position becomes magnetic; the north pole is always at the lower extremity. Iron has been met with in a nearly pure metallic state, in considerable masses, reputed to have fallen from the skies. This meteoric iron always contains a portion of nickel, which, it is worthy of remark, is also found, by analysis, to be a constituent part of all those stones which, in various parts of the world, have been known to fall from the atmosphere, and are, therefore, denominated *meteoric stones*. A mass of meteoric iron was found in Peru, weighing 15 tons. It was compact in substance externally, and marked with impressions as if of hands and feet, of enormous size, and of the claws of birds; internally, it presented many cavities.

It is unnecessary to attempt the enumeration of the uses to which iron is put by the ingenuity of man. Steel is an artificial combination with carbon. Plumbago, or black lead, is a natural combination of the same materials.

Antimony occurs, in the native state, alloyed by iron and silver; in its ores, it is combined with sulphur and other materials. *Zinc* occurs in similar combinations. *Nickel* is a rare metal, and is found in the state of an oxide, and also combined with arsenic. *Arsenic* is involved, in small portions, in several of the native metals, and in the ores of some others. *Cobalt* is not very plentiful: in its ores, it occurs with iron and arsenic.

The remainder of the metals are comparatively rare, and do not require a minute description.

The whole of the elementary constituent parts of minerals, at present known, are not fewer than fifty. They comprise twenty-eight metals, the bases of ten earths, and of three alkalies, with nine other elementary substances. Since the discovery of the metallic nature of the earths, the chemist can no longer regard them as elements, but as metallic oxides, or unknown bases combined with oxygen. Yet, as the bases of the earths never occur in nature in an uncombined state, the mineralogist may still speak of the earths as simple substances.

BOTANY.

Botany is the science of the vegetable kingdom, and is one of the most attractive, useful, and extensive departments of human knowledge. It is, above every other, the science of beauty. There are few plants which are not beautiful, considered as separate individuals, and in all the parts of their individual organization ; and there is a beauty in the grouping of plants, whether as grouped by nature, or by skilful art, to

which there is nothing equal in that of any of the other productions of nature. The landscape is the object which mankind most generally admire; and the landscape owes its principal if not its only charms to its vegetation. Rocks have, no doubt, their grandeur; and there is a beauty in running waters, and even in placid lakes; but, let the rock be naked of vegetation down to and around its base, and its grandeur is painful,—it seems a ruin. So, also, if the water is denuded of its meadows, its thickets, its groves, its shady trees, and its plants of humbler growth, it is no longer beautiful; for an expanse of water, or a rolling torrent, amid perfect sterility, makes the contemplation of that sterility more gloomy, from the feeling that this water, by being unproductive, is so much of the bounty of nature running to waste. It is needless, however, to expatiate on this part of the subject; for every one feels it more forcibly, in the contemplation of nature itself, than it could be rendered by even the most labored description.

As little is it necessary to descant on the usefulness of the study of vegetables; for we have only to look around us, and observe how much of our food, our clothing, our furniture, our habitations, the implements of our work, and the instruments of all our enjoyment, is derived from the vegetable kingdom, in order to see that it is this kingdom which is the grand foundation of all our arts, and one of the instruments by which man has been civilized, and enabled to turn all the other productions of nature to whatever use he makes of them. For instance, there can be no civilization without fire; indeed, fire is one of the chief distinctions of man, in the lowest states of society, from

the other animals, many of which are superior to him in strength, in speed, in the acuteness of their senses, and even in some of their artifices: there can be no fire without fuel; and all fuel is vegetable. It is by means of vegetables — of the timber which forms the ship, and the fibres of which the cordage and sails are made — that man has been enabled to extend his knowledge to every portion of the globe, and partake, at most points of its surface, of the riches of all. No one can help admiring the exquisite beauty of many flowers, and the delicious flavor of many fruits, which are habitually brought from a distance of many thousand miles over the sea; and for all of these, and for every foreign commodity, and for every piece of foreign information, that we can enjoy or obtain, we are indebted to the vegetable ship.

A subject which is of so vast and varied usefulness, and which, at the same time, has so much of beauty to recommend it, cannot receive too much of our attention; and, the more to induce us to bestow this attention, we find, by experience, that the productions of the vegetable kingdom are much more obedient to skilful cultivation than those of any other department of nature. Compare an ordinary field under crop with a neglected common, of precisely the same soil, and in a situation exactly similar, — or compare a moderately cultivated garden with a neglected heath, — and they appear as if they were not parts of the same country.

Take some of the most common, but, at the same time, the most useful, of those vegetables which we cultivate as food, and consider what human skill has done for them. Where is there a native grain like wheat, a

native fruit like the apple, a native bud like the cauliflower, or a native root like the potato? The last is a remarkable instance of what cultivation can do; and its history from the wild plant happens to be known. The potato is a native of the mountains of tropical America, and, when found wild there, it is barely, if at all, eatable. These are but a few instances out of many, in which plants, naturally of little value, have been rendered very valuable by cultivation, in climates much less favored by nature than those in which they are found native; but even these may suffice to show the vast advantage which has been derived from studying the nature of vegetables; and as the number, of which the improvement by culture has been ascertained, is very small compared with those of which it has not, the field open for further improvement is as wide as it is inviting.

The history of vegetable science is brief and imperfect. The Greek philosophers, having derived their knowledge principally from Asia and Egypt, examined the laws of vegetable life very superficially, from their want of means, and their ignorance of chemistry. They at once arrived at general conclusions, and asserted that plants possessed rational souls, capable of the mental powers, and indicative of the organization of animals. Aristotle, 384 B. C., published his works on natural history, in which he formed a more rational theory, though little corresponding with that of the present day. Theophrastus, the pupil of Aristotle, is said to have been the founder of philosophical botany; he wrote several works on the subject. Dioscorides compiled a work containing a partial descrip-

tion, particularly of the medicinal qualities of 1200 plants, in the first year of the Christian era; and this was the only source of botanical knowledge for *fifteen centuries.* To this, Persian and Arabian physicians added 200 plants.

The elder Pliny and Galen contributed also to a knowledge of the properties of plants. But the Germans were first to found historical botany, and to commence scientific classification. The Italians followed, and then the Belgians. The French greatly increased the number of plants, and reformed the nomenclature; so that, at the beginning of the 17th century, the number of species known was 5500. This number continued to increase, by an awakened attention to the subject, and the united labors of others in various countries, until Linnæus appeared with his *Species Plantarum*, when the number of plants known was 7300. Since this time, it has increased most wonderfully. A more systematic or *natural method* of arrangement has been introduced by Jussieu, Condolle, Mirbel, and others; and the whole now presents, in every department, the most attractive interest. The progress of the science of vegetables, botanical and agricultural, has been unexampled in the history of any other science. But, however interesting this may be, we lack time and space to notice it further. Chemistry, the chief source of improvement in this branch of science, has recently disclosed, through Liebeg and others, the most important facts, as to the nature, requirements, and properties, of fruits and plants, and shed a noonday light on the path of the practical agriculturist.

VEGETABLE PHYSIOLOGY, &c.

That portion of the science of botany, which treats of the life and growth of plants, is called *vegetable physiology*, and is one of the most attractive portions of the science. Of this topic, we can only give a hasty outline.

* Plants are organized living bodies, which, like those of animals, are composed of solids and fluids. They are without powers of locomotion, and, it is thought, of voluntary motion. They are fixed to the earth by roots, from which they rise upward by a stem which throws out branches that, in their turn, give out others, all bearing leaves, flowers, fruits, and seeds. The word *plant* literally means " fixed " or " rooted ; " but in botany, it signifies all productions of the vegetable kingdom. These are of three kinds—*herbs*, *shrubs*, and *trees ;* they are *annual*, perishing within the year ; *biennial*, flowering the second year, and then perishing ; or *perennial*, surviving many years. They are *deciduous* when their leaves fade in autumn, and *evergreen* when these are constantly renewed, as with all resinous trees. They are *indigenous*, or native, and *exotic*, or foreign. The solid parts of plants consist mostly of *cellular substance*, *woody fibre*, *pith*, *bark*, &c. ; and of fluids and juices, of various degrees of consistence, as *volatile* and *fixed oils*, *gums*, *resins*, *air*,

* In the preparation of this article, we are largely indebted to a work entitled the Vegetable Kingdom, or Hand Book of Plants and Fruits, by L. D. Chapin,—a work which we heartily recommend, as combining, in a most attractive form, the entertaining and useful facts of this important subject.

water, &c. These are circulated in various ways, and in numerous vessels and organs, each containing particular substances, and performing peculiar functions.

The *fluids*, or juices, moving in the vessels of plants, contain the nourishment, and constitute the essential means by which food is assimilated with their solid substances. A correspondence is thus observable between their functions, and the circulation of the blood, and other physiological phenomena, of animals. They possess powers of motion, irritability, and of reproduction; they breathe, sleep, digest, and perspire. Their peculiar individual character is preserved by their vital functions, which constitute their life; and when they cease, their bodies are exposed to the chemical processes which act alike on all inorganic substances, and they die.

> "See dying vegetables life sustain;
> See life, dissolving, vegetate again."

The *circulation*, or motion, of the juices of plants, is thought to be mechanical, the result of their irritability, the vessels acting as capillary tubes, &c. This irritability is destroyed by shocks of electricity, as with animals. Heat and light greatly increase this circulation, as in the spring of the year; while cold as readily checks or suspends it, as in autumn and winter. Long-continued heat, and rapidity of circulation, as in summer, exhausts their power of irritability, till in autumn it is slow, and their fluids are thick, as in animal life, both in regard to season and old age. Their repose, too, after the activity of the day, and their revival on

the appearance of light, are not less remarkable than with man, or lower animals, under like circumstances.

The *breathing of plants* is their absorption and exhalations — physiological facts as notable as any other in the vegetable or animal economy. This is performed by, and is especially observable in, the leaves. A plant growing under ice constantly emits bubbles of pure oxygen, which rise to escape. Placed also in a tumbler of water, exposed to the sun, it is soon seen to be covered with air-bubbles, which rise to the surface and burst. The inspiration of carbonic acid through the leaves of plants is as constant, and in quantity still more abundant. By this they live and furnish their organs with nourishment; and, by their expirations during the day, they afford the vital gaseous principle, oxygen, which is as necessary to the life of man and the animal world as to that of plants; withdrawing, at the same time, carbonic acid, which is most hurtful to animal life. Besides gases, they also exhale liquids, which, in a common-sized tree, amount to 30 pounds a day.

Their odor, thus exhaled, consists of *volatile oils*, which, in quantity, are proportionate to their volatility, their nature, light, heat, &c. *Their taste* depends on like circumstances, the chemical character of their constituents and the nature of the soil. The *color of plants* resides in their cellular substance, beneath the scarf skin, or epidermis, and depends on the peculiar functions of their organs, their situation, heat, &c. Green leaves placed in the dark become yellow, and then white. Young leaves grown in the dark turn from white to yellow, and then to green, on exposure to

light. Blossoms raised in the dark are not materially changed by light. Plants are lighter by combining with oxygen, and darker on parting with it. Completely saturated with it, they become yellow, as with the leaves in autumn; but under other circumstances, when exposed, they turn to green. The light of a lamp and that of the moon produces no sensible difference in effect.

Secretions and *excretions* are likewise remarkable functions of plants. All that is healthful and nutritive they secrete for their food and development, and all that is baneful and unproductive they reject and excrete through their roots. These withdraw from the soil its various qualities, which constitute their life, health, and the perfection of their fruit; combining and assimilating all that is essential for these purposes, and casting off all that is useless or poisonous, yet that which may be eminently useful, nevertheless, for other plants.

The *existence* and *growth of plants* depend, as with animals, on the reception and assimilation of food. A knowledge, therefore, of the *kind* of nutriment they require is of great importance in vegetable physiology, as well as in practical agriculture. A beautiful relation is thus seen between the organic and inorganic kingdoms. Inorganic matter affords food for plants, plants afford food for animals, and both afford food for man. Men and animals require substances that have life and organization; but plants require inanimate and inorganic matter. Both are apparent machines of greater or less complexity, each depending on the other, and acting to produce a determinate end.

The *changes* produced in plants, by the assimilation

of the various substances of which they are composed, are the results of chemical action, and are traceable from the germ to the full-grown plant and fruit. Water and carbon are resolved into their constituent parts, and these enter into new forms and combinations, to constitute their solid portions. The hydrogen of the water unites with the carbon, received through the leaves from the air, to form oils, resins, sugar, &c. The oxygen of the water combines with fluids to form acids, &c., and is also given off from the leaves in the form of gas.

The *reproduction of plants* is by evolution, which, in process and effect, is similar to that of animals. They are endowed with organs which distinguish sexes, and which are generally observable, but which change after evolution. The *pollen* or *farina*, the seminal principle of plants, is contained in vessels called *anthers*. A part of this penetrates the *stigma*, the head of the *pistil*, and is conveyed to the ovary of particular plants, and there the germ or *ovules* are effected. Both sexes are united in one flower, in most plants; in others they are separated; and the former is, therefore, called a perfect flower, while the latter is called male and female. These last stand on one stem, or are attached to different plants. Evolution is, consequently, most perfect, and most readily effected, in the perfect flowers, as they are called, and likewise when the stem has male and female blossoms. But where the two sexes are entirely separated, evolution takes place only where the plants are sufficiently near for the pollen of one to be carried by the wind, by insects, or by artificial means, to the other. Should this not take place,

the germ falls off, or the partial fruit is incapable of germination. Glands within the flowers secrete honey, and attract insects, which powder parts of their body with pollen, and when visiting flowers of another kind, they deposit it. In others, it is said, also, where perfect flowers of the two sexes are not near, small flies, being attracted by the honey of one flower, are suddenly enclosed by it, and in their endeavors to escape, necessarily deposit the pollen obtained from other flowers. On this system of sexes, Linnæus founded his arrangement of plants.

The *substances of plants* are in general said to consist of wood, gum, fecula or starch, sugar, gluten, albumen, fibrine, gelatin, caoutchouc or India rubber, wax, fixed and volatile oils, camphor-resin, gum-resin, balsam, extract, tannin, indigo, acid, aroma, the bitter, the acid and narcotic principles, ligneous fibre, &c. Many of these, however, are convertible into one another, by heat, air, moisture, or alkalies, which change, more or less, the relative proportions of their constituents. Modern chemistry has added others, or arranged the same under new names and forms of combination, and much diminished and changed the terms by which vegetable substances have been known. A chemical analysis has proved the substances to be carbon, oxygen, hydrogen, nitrogen, sulphur, silex, oxide of iron, magnesia, carbonate of lime, potash, &c.; and the various parts of plants are composed of these, in different proportions. The formation of substances composing plants is the result of chemical operations during their growth and the development of fruit. The process of combining the original elements, their absorption by heat and light, their unition in various

forms and combinations, and also the resolving of original substances into other forms and compounds, constitute more especially the important and interesting science of *organic chemistry*.

Principles of plants. The *proximate principles* of plants are the products of chemical combinations effected by the action of the vital principle. Such are the vegetable acids, wax, resins, the fixed and volatile oils, &c. The *ultimate principles* are the elements composing the proximate principles, as carbon, oxygen, and hydrogen, and these are proportionate to the nature and quantity of these elements. Thus those substances composed of them form one class of proximate principles, and those, with the addition of nitrogen, another class. Those of the one class have an *excess* of oxygen, (the general acidifying principle,) and therefore constitute the

Vegetable acids. *Acetic acid*, or pure vinegar, is commonly produced by the fermentation of wine, cider, &c.: it is also found pure in the elm. *Malic acid* may be obtained from green apples, and barberries. *Oxalic acid* is found in a species of the sorrel, or the genera *oxalis* and *rumex*. *Tartaric acid* is obtained from the tamarind, cranberry, &c.; and when combined with potash, forms *cream of tartar*. *Citric acid* is found in the lemon, and is mixed with the malic acid in the gooseberry, cherry, and strawberry. *Quinic acid* is obtained from the Peruvian bark. *Gallic acid* is from the oak and sumach, and is very astringent. *Benzoic acid* is found in the *laurus*, *benzoin*, and *vanilla;* it is highly aromatic, and is the agreeable odor of balms. *Prussic acid*, an active

poison, is obtained from peach meats and blossoms, bitter almonds, cherry leaves and meats.

Gums, *sugar*, &c., compose that order of proximate principles in which hydrogen and oxygen are in the proportion to form water. These unite with water, but have little taste or smell. They compose *gum arabic*, the common gums of the peach, cherry, and other trees. *Sugar* is from the sugar-cane, maple-trees, beets, corn-stalks, pumpkins, sweet apples, and most vegetables with a sweet taste.

Oils, *wax*, *resins*, &c., in which hydrogen is in excess, are of the second order of proximate principles. They do not unite with water. *Oils* are *fixed*, as oil of almonds, olives, flax-seed, linseed oil; and *volatile*, which have aromatic odors, that fly off when exposed to the air, as the oils of orange, lavender, rose, jasmine, and peppermint; and, when mixed with alcohol, they form *essences*. The *aroma* is the volatile or odoriferous part exhaled from aromatic plants, especially abundant in warm climates. *Wax* is found on the fruit of the bayberry; and bees-wax is produced by bees from the pollen of flowers. *Resins* exude from the pine, &c.; they are insoluble in water, and inflammable. Mixed with volatile oils, they form *balsams*, which are thick and inflammable, as balsam of tolu, copayva, &c. When mixed with gums, they are then *gum-resins*, as gamboge, guaiacum, aloes, assafœtida, &c. *Gum-elastic*, or caoutchouc, from South America, and some other trees of the tropics, possess remarkable properties. The juice of the common milk-weed is said to be similar to that of the India rubber plant. The valuable properties of these substances

would form the subject of a treatise too extensive for our limits.

The *second class* of proximate principles are composed of the ultimate elements we have mentioned, with nitrogen. Such are *opium*, the narcotic principle of the poppy ; *hematine*, the coloring principle of Campeachy wood ; *indigo*, from species of the indigo plant ; *gluten*, from the cotyledons of leguminous plants, as beans and peas, also from the albumen of wheat, rye, &c., when separated from the starch. *Jelly* is the juice of succulent fruits, as apples, quinces, currants, &c. The coloring principle of plants gives to them their green color, by the aid of light. It is changed, as in autumn, by the formation of an acid. Thus a drop of an acid on the green part will turn it to a brown. The coloring matter of some plants has never been obtained separate from the plant, as in logwood and saffron. The red coloring of fruit is produced by the combination of an acid with a blue coloring principle, as an acid will do with all vegetable blues ; this is deeper in proportion to the quantity of acid. An acid with iron is the common coloring principle of flowers.

The *composition of the sap of plants* is from the before-mentioned elements, and water holding in solution the earths and their metallic bases, alkaline salts, &c., with vegetable and animal substances. It is not obtained pure, being always mixed with the proximate principles before mentioned ; and it differs, in plants, in proportion to those principles. The power or property of a plant to secrete one kind of substance, and not another, depends on its constitutional peculiarities, as

with the races of men in the formation of their different colors. Water is always a predominant constituent of the sap of plants. An analysis of the sap of the elm gives water, volatile matter, acetate of potash, carbonate of lime, sulphate of potash, and vegetable matter; of the beech, water, acetate of lime, acetate of potash, gallic acid, tannin, mucous extract, acetate of alumina, etc. These show the differences in the elements of the sap; they also differ materially in their proportions. The odor, taste, nutritive and medicinal qualities, color, &c., are all the result of these elements, variously combined. The elements are the same in substances of very different character, solids as well as fluids; but their mode of combination may form vinegar or a liquid in one, and sugar or a solid in another. By knowing these elements and their proportions, similar substances may be produced by the chemist, but not the form and organization of the plant, these being alone the work of nature, in conformity with laws established by Supreme Wisdom.

The *nourishment of plants.* Being deprived of the powers of locomotion, plants must have organs to obtain their food from the situation in which it is placed, and also for assimilating it. This food is in a liquid or aëriform state. The solid particles held in liquids must be in a very fine state, as commonly diffused in water or rain. When placed in water, plants bloom, but the nourishment of the water is soon exhausted. Distilled water has lost that nourishment, or its carbonic acid gas, &c., and plants soon die in it.

Spongelets or *suckers*, like the organs of insects that live by suction, are minute, sponge-like vessels, on the

point of the rootlets, radicles, or small fibres. These pores admit only of fine particles dissolved in water; otherwise they become obstructed, and the plant perishes. The pores or suckers of leaves are similar, and perform similar functions.

The *sap vessels* are congeries of fine tubes, straight and curved, forming lace-work, or they are of a beautiful spiral form. The *straight vessels* are hollow threadlets, fifty times finer than a hair, and forming, together, large tubes. The *spiral vessels* act singly, or in bundles, in every part of the plant, except the bark. The *circulation* through these, upwards and downwards, is exceedingly curious. The *organs of aëration* are not like those of the lungs, any more than the pith in the circulation is like the heart of animals; yet analogous functions are performed by them in both. They breathe, and it is by the air they are chiefly nourished.

Organs of sensation in plants. It has been thought by some that plants are endowed with sensation, sentiments, and propensities. Nervous organs have been disclosed, it is said, in the *sensitive* and other plants. There is, at the base of the leaf-stalk of this plant, a swelling collar, constituted of a delicate tissue of cells, on whieh the motion of the leaves depends. The under part being cut away, the leaf bends down, and cannot again rise; and the upper part being cut, it cannot bend. These are acted on, it is believed, by nervous globules, or grains, or *ganglia*, as diffused in all plants by medullary vessels. The effects of experiments certainly show an analogy between plants and animals, but nothing more. Leaves and flowers turn to the light

when twisted; these curl up and die when watered with poisons. Twining plants twine from right to left, or left to right, according to species.

The *existence of plants* has been compared to that of animals when asleep, their functions proceeding during the time without consciousness. A seed placed in the earth is similar, in its nature, to the egg of an animal; and the effects of the earth would seem not unlike that of sitting upon it, or the development of the young of amphibious animals with the egg covered by the earth. It is obviously very difficult to determine at what point vegetable life ends and animal life begins. The sponge is, in many respects, less sensitive than some plants, yet it is ranked among animals; and so also with corals. Although we might show how plants grow, yet it may not appear plain how they live. They live, it is true, like animals, by the food they receive and assimilate; yet the generation of the vital principle which constitutes life is not explained. By observing the facts which are hereafter stated, it will be seen that there are clear distinctions between the animal and vegetable kingdoms, notwithstanding the analogies of life we have noticed.

Age of plants. Many small funguses, called *moulds*, live but a few hours, or not longer, at most, than a few days. Garden plants and mosses live but one season, dying of old age as soon as they ripen their seeds. Others live two years, and sometimes three, if their flowering is prevented, such as the fox-glove and hollyhock. These are the annual and biennial shrubs, herbs, &c. Many live not only through the winter, but are perpetually or perennially green. Such are ever-

greens or forest trees. These live oftentimes for many centuries, producing annually new leaves. Thus the olive, vine, oak, cedar, and chestnut, live 300, and even 1000 years. The dragon's-blood of Teneriffe is estimated to be 2000, or more, years old; and the banian may be 6000. The interior of trees often becomes too compact for the sap to circulate, or for the formation of new vessels; its moisture passes into younger wood, and the fibres shrink and become powder; but the outer parts live, and the tree survives, even for centuries.

Laws and *vital principles.* Inorganic matter is the medium through which organic matter derives its organization and vitality. This matter, in its ordinary state, undergoing neither the process of organization nor of decomposition, belongs especially to the mineral kingdom. From this, then, the vegetable kingdom mainly derives its powers; and from the vegetable kingdom are derived those of the animal kingdom. It is only when animal and vegetable substances have been deprived of vitality, and are no longer subject to the laws of organic matter, but have become, by death, subject to the laws of inorganic matter, that vegetables are in part supported by them. But animals are supported by organic matter, or that which has had vitality, and before the laws of inorganic matter have operated upon it. It will be perceived that inorganic matter, or that of the mineral kingdom, possesses the same properties, when divided or ground to powder, that it does in the mass; *i. e.* each particle possesses those properties in proportion to its size; while the organic parts of animals or of vegetables, if thus crushed or divided,

are deprived by death of the vital forces which distinguished them from inorganic matter.

The *seed of a plant*, if placed in the earth, forms a living plant, which, from its incipiency, opposes inorganic laws, or those of decomposition. The vital principle which it has received from the seed, and which the seed has parted with, together with a portion of its substance, for its support, continues to animate the plant; while the remainder of the seed has thereby become subject to the inorganic laws, and rots, or is decomposed in the ground. The plant lives and flourishes; and, by the force of its vital powers, thus obtained, appropriates inorganic matter to its support and the development of its organs, until, by violence or the exhaustion of its vital energies at maturity, it is at length, and in turn, subjected to the force of the inorganic laws; it dies, and is decomposed, either in the ground or by being consumed by animals. The seed originally derived its vital principle from its parent plant, through its pericarp, or fruit, and retained it within its envelopes until buried, and excited to germination by the heat and moisture within the earth, when it gave it to its offspring.

During the period from the birth to the death of a plant, periods of repose intervene, as with biennial and perennial plants in winter. It loses its leaves, the principal means of its support, and remains partially dormant, until awakened to action by the heat of returning spring, when its leaves are renewed, and its dormant energies call forth new shoots, buds, and blossoms, and the scene of life, health, vigor, and action, is reënacted.

Light is evidently one of the "necessaries of life,"

and plays an important part in vegetation and the economy of plants. By it they form their combustible parts. The carbon they receive must be, in some way, modified by its influence before it can become a constituent of the plant. During the night, they probably do little more than to digest the food they have received during the day, and to separate and give off that which is not found nutritious. Light is a primary agent from the time the plant emerges from the soil to its death. Its nature becomes changed by its absence, so that the observer would scarcely recognize its identity by its form, color, taste, or odor. If a branch of any spreading plant penetrates, in its growth, a subterranean place, its character becomes not only thus changed, but it is found composed almost entirely of water, and assumes the nature of a fungus, so that all of its native beauties and virtues are lost; it is a mere pulp deprived of its resinous qualities. The acid taste of some vegetables, as the endive and celery, may, however, be corrected by bleaching.

Diseases of plants. These arise from many causes, as with man and lower animals. They may be detected and cured by a careful observance of the nature and wants of plants. The change in the color of the leaves of the box and holly is said to be a disease, or disordered condition, of the juices. Too much or too little food, or that which is poisonous, produces diseases. Too little or too much light, heat, air, water, and soil, an excess of light, so as to cause the escape of too much oxygen, or too rapid a deposit of carbon, are also causes of disease. By a knowledge of the properties and characteristics of plants, we may per-

ceive their wants, and frequently apply remedies adapted to their diseased condition. Their health is often affected by external injuries. Rains and winds also injure them, oftentimes. Smoke obstructs the pores of the leaves, and is thereby greatly prejudicial.

Animals are a frequent cause of disease in plants. Some penetrate the bark, and deposit their eggs, producing larvæ, and the insect *cynips*. By one kind of these, protuberances are produced, as the nutgall of oaks, apple or berry galls. Some prey on the juices, as with the insect *cochineal*, a species of which is so valuable for dyeing a scarlet color. The Mexican plant *cactus cochinilifer* is that which they feed upon. Disease is likewise produced by contiguity with other plants, either by ejecting deleterious matter from their roots, or withdrawing that which is necessary for one or the other. Mosses and lichens attach themselves to trees, and absorb moisture, or attract insects, both of which destroy the wood; they do not, however, feed on the juices, and are, therefore, called *false parasites*. The mistletoe pierces the bark and feeds on the juices, and is a true parasite. Another parasite, called the *pterospora*, is found on the leaves and branches of trees. *Smut* and *rot* are *fungi*, the former fastening itself on the ears of cereal grains, and the latter preying on the seeds. If these seeds be planted, the disease will be continued in the plant. *Rust* and *ergot* are also *fungi*, the one a disease of rye, and the other of grasses. As plants renew their parts annually, they seem less liable to be affected by old age; still their powers of renewal, or vital principle, become exhausted in time, as with animals. In annual plants,

the production and maturing of fruit exhaust their energies during the year, and in biennials in two years. These, however, as with perennials, depend much on their constitution and the amount of their fruit, as with the apple-tree, which, being very fruitful, does not often attain to so great an age as the oak, the fruit of which is light.

The *effects produced by insects* on plants are vastly greater than in producing deformities. Like great fires, however, they may often prove a benefit, and maintain a balance among the various species of plants; for the devastating effects of these insignificant agents are wonderful. Scarcely a plant is without one or more species of insect. The diseases they produce often constitute an important article of food, medicine, and commerce, as we have said, in the *cactus*, or cochineal insect; the *lac* insect; the *cantharia*, or Spanish fly; the gall apples, and the nutgalls.

The sweeping destruction produced by the locust affords a striking discrepancy between the magnitude of the means and that of the effects. They can strip entirely of their foliage thousands of square miles of forest-trees during one brief visit, and annihilate every appearance of vegetation; as when they thus scourged Masinissa, causing the death by famine of more than 800,000 persons! Compared with such effects, earthquakes and volcanoes dwindle into insignificance.

Their numbers are so vast as often to overshadow immense tracts of country. The swarm which passed over Smyrna, like a living cloud, for three days and nights, was calculated to be 900 feet deep, more than 40 miles wide, and 50 miles in length! The

number exceeded 168,608,563,200,000, and the magnitude of the mass, if gathered into a heap, would exceed by more than 1030 times that of the largest pyramid of Egypt, or would encircle the whole earth with a belt a mile and a furlong wide. When borne down by tempests, their bodies have overspread large tracts of country 4 feet deep, or formed, when thus driven into the sea, windrows along the shore 3 or 4 feet deep, for 50 miles in extent!

The *aphides*, or rose bugs, the flies of the turnip fields, and the timber grubs, are also terribly destructive. The "great goat moth" is likewise a powerfully destructive insect to plants. Its larvæ are proved to increase their weight 140 times within an hour, and, when full grown, are 72,000 times heavier than when hatched! The *termes bellicosus* lays sixty eggs per minute, and continues to do so, without interruption, for an incredible time; thus laying, it is calculated, 3600 eggs per hour, or 86,400 per day! The common flesh fly, it is said, will give birth to 20,000 young; and the three flies, *musca vomitoria*, Linnæus and others have said, can devour a dead horse as quick as a lion, or commit more ravages than an elephant. They are thus important scavengers. The pine forests of Germany have sustained immense injuries from a small beetle, which has deposited 80,000 larvæ in one tree. Preying on the inner bark, they have thus destroyed, in one forest, 1,500,000 trees, and then, on maturity, taken wing, and flown to other forests with like results. It was a subject of great wonder at one time, in London, how the elm-trees in some of the parks became completely stripped of their bark. Sus-

pecting it to be caused by soldiers, many were arrested, and watches stationed to secure the depredators; still the work of destruction ceased not. Various other causes were supposed, and severe measures taken to punish the culprits; until, at length, they were found to be no others than insects, which were ultimately checked in their career by art.

The *economy of plants*, as observed in their habits, is strikingly illustrative of the harmony of nature. We see them adapted to the peculiarities of their situations. If indigenous to the tropical climate, they cannot live in our temperate zone without the aid of art; if inhabitants of the valley, they cannot dwell on the mountain's summit; nor, if the rugged tenants of the bleak and frosty mountain, can they endure the enervating dalliance of the luxurious vale; nor can either dwell, with the aquatic plant, immersed in a liquid element. We have noticed many of the habits of plants; and, in many ways which we cannot particularly notice, they minister to our wants as food, clothing, medicines, in the arts, and to the support of inferior animals. The interest with which they must be viewed, with their numberless shoots urging into life and action their millions of buds, that are expanded into light and being by the genial sun, rivalling one another in their efforts to produce the fairest flower, and choicest fruit,—these render them objects of peculiar attention. But a change comes over them, as we have seen, and as we daily witness with fellow-mortals. They die and mingle with the soil, and from their decomposed remains spring up new beings.

The *various forms of plants*, in this connection, can-

not fail to strike us with wonder. Although this is remarkable in the 100,000 different species of insects, yet the variations are not so obvious in the range of such minute objects as in plants, nor are they more prolific in wonders. In every situation capable of sustaining life we find plants arise, and continue their species in endless perpetuity. The germs are every where found where the soil is upturned, and where they may have remained dormant perhaps for centuries. Islands formed of coral reefs, and even sterile rocks, cinders, and lava of recent volcanoes, are found covered with vegetable forms. The germs that float invisibly in the air successively follow each other, and plant the most barren places with verdure, which, rising from grasses to shrubs, and from shrubs to trees, soon present all the varied forms of meadows, thickets, and forests. Thus, considered in reference to their utility, the beauty of their forms and colors, their fruit and fragrance, or the continuation of their species, they forcibly impress us at all times with admiration and delight.

The *utility of plants* is unbounded and illimitable. Nowhere do they rise in vain. The lofty tree, whatever its intrinsic properties, presents its cooling and refreshing shades for flocks and herds, and offers an asylum for the insect tribe, and for the songsters of the air. As food, the bread-fruit tree of the Pacific, and the cabbage-tree of our own and other southern climes, the sugar-maple of the United States, the tea-tree of China, the sugar-cane, the cotton-shrub, and the coffee-tree, and the innumerable fruit-trees, which every where yield in rich profusion their varied prod-

ucts; the fountain-tree of the Canaries, that yields pure water; the tallow-tree of China; the mulberry-tree, nourishing myriads of beings that industriously supply us with silks; the salt-tree of Chili, that daily supplies the people with salt; the cinnamon, pimento, and clove, that furnish our spices; the Peruvian bark, the senna, manna, and innumerable other medicinal plants; those, too, yielding their healing balsams, turpentine, resins, oils, and gums,—all, all furnish us with their invaluable products. Nor are they less important in protecting us by the buildings we raise with them, or in the conveniences and luxuries they afford us by the ships we build of them to transport the products of one clime and people to those of another.

Shrubs and *herbs* also supply us with every variety of food and useful product. There the golden wheat presents its abundant crops, and here the flowing oats and potatoes, the loaded pea, the swelling turnip, beet, and carrot, the luxuriant grass and bountiful corn, crown the earth's surface with life and nourishment; while the universal smiles of variously-tinted flowers invite us abroad to view the charms and inhale the odors of their fragrant breath. All here spread out before us the rich bounties and varied delights of vegetable nature. Well may it be said, with all these in view, that "In reason's ear they become preachers."

CLASSIFICATION OF PLANTS.

According to the latest researches of naturalists, about 80,000 plants of distinct specific forms have been discovered; but it is believed that as many more remain to be made known, and additions to the list are constantly taking place. For the sake of order and classi-

fication, as in the case of the animal kingdom, all plants, from the lowest to the highest forms of vegetation, are arranged in a progressive series of groups or families, the members of which possess a common resemblance, or are otherwise allied in character. According to the Linnæan system, the whole vegetable kingdom is arranged in two grand divisions — namely, *Phænogamia*, plants having visible flowers, and *Cryptogamia*, plants having no visible flowers. The whole are also divided into classes, orders, genera, and species, each species containing a number of varieties.

Lower Forms of Vegetation. — Cryptogamia. Among these are included the *fungi*, the *musci*, (mosses,) *hepaticæ*, (liverworts,) *lichines*, (lichens,) *algæ*, (seaweeds,) and *filices*, (ferns,) &c.

Fungi. These may be placed at the very bottom of the vegetable scale, and are observable in a great variety of forms, and, among others, mushrooms, toadstools, puff-balls, the fungous dryrot, fermentation, mildew, and mould. These afford a most interesting topic of discussion; but we have room only to name them.

Algæ. It is generally allowed that these embrace the most minute forms of vegetation not of a fungous character. One of these forms is that which has vulgarly been called *red snow*, or *bloody rain*. A shower of red-colored rain or snow is by no means a rare phenomenon in the northern parts of Europe, or within the arctic circle; and the tinging matter, which has been accurately examined, is found either to proceed from the incorporation of vegetables or animalcules, both too small to be seen by the naked eye. The coloring vegetable matter is an aggregation of an infinitude of plants either sucked up by a water-spout into the atmosphere, or overtaken while carried along by the winds, and brought down by the falling drops. On the stones by the side of brooks, we may sometimes observe a similar reddish coloring matter, which, if not caused by metallic ores, will generally be found to be a primitive kind of vegetation. When touched, it feels slippery, and on examination by a microscope, it is observed to contain myriads of plants, each consisting of a small vesicle or globule, which, on arriving at maturity, expands, bursts, and liberates germs of its own species. This excessively humble plant is classed

with the algæ, as being the nearest to it in character, although these plants are for the most part of a large size, and grow principally on rocks in the sea.

The object which nature has in view by the germination and dispersal of the algæ, mosses, and lichens, is clearly that of preparing the way for other plants, destined to subserve important purposes in the circle of nature.

HIGHER FORMS OF VEGETATION. — PHÆNOGAMIA. We now ascend to the second great division in the vegetable kingdom, containing plants which flower, and possess the attributes of distinct seeds, roots, stems, branches, and leaves.

Seeds are the offspring of plants. They are discharged spontaneously from the parent, and such is the care that nature has taken for their preservation, that many of them will remain uninjured for centuries, till a favorable opportunity is presented for their development. They contain a vital principle or embryo, which is in all respects like the parent, unless art has interfered to change its form or qualities. When seeds are ripe, they are shed from the capsules, or from the other parts to which they are attached, and are then covered with one, two, or three integuments, to preserve them till the season arrives when other favorable circumstances conspire to produce germination. A perfect seed is one of the most wonderful productions in nature! It contains a living principle within an organized body of cellular membrane, capable of indefinite expansion. When placed in the earth, by the influence of heat and moisture expansion takes place, the outer covering is burst asunder, the root

descends in search of food and moisture, and the stalk then ascends, to put forth its various members of branch, leaf, and flower.

The general form of seeds is kidney-shaped: some are provided with appendages for defence; others with little hooks or wings, to assist their dispersion. The various means employed by nature for the scattering of seeds, such as winds, rivers, rains, birds, animals, and man, afford a striking instance of that far-seeing wisdom which characterizes the great Legislator of the universe. All seeds are enclosed in a thin fibre of cellular tissue, and many are further protected by pods and shells. Some are covered with a pulpy or a fleshy substance, constituting many of our delicious fruits, such as pears, apples, plums, cherries, peaches, &c.


The *root* is at first a spear-shaped body, descending directly downward into the earth, either avoiding the light, or seeking the moisture. It soon throws off small fibres from its point and along its sides. These, in their turn, throw off branches and fibres — the whole process being continued so long as the plant above

requires it. The fibres are the real mouths by which the moisture and nutriment of the plant are received.

The *trunk* or *axis* of a plant is that columnar body, which, if above ground, serves to support and elevate the fructification. It assumes many forms and characters, as to bulk, structure, position, place, and duration. It appears as a tuber, a bulb, a scape, a culm, or as a woody column. It varies in size from that of a bristle to a trunk of many feet in diameter. In structure, stems are hollow or solid, jointed or simple, single or numerous. In position, they are erect, inclining, prostrate, or involving. They rise in the air, creep on the surface, or enter deep into the ground. They are succulent or woody: if the former, they are quickly perishable; if the latter, they are more or less durable.

The *pith* occupies the centre of the stem, and constitutes the principal part of the bulk of the seedling, and of every young shoot. It is more or less filled with a spongy matter, easily permeable by fluids. There seems to be no action in the pith, except as a duct, after the first year; for, as it increases in age, it decreases in volume, and in old trees becomes almost obliterated.

Of the wood. The first layer of this principal member of a stem is simultaneously produced with the pith which it surrounds. During its growth it appears in three different states; at first, it is like thin, colorless jelly, in which state it is called *cambium;* next, it gains a substance like gum, showing faint signs of organization; and lastly, as perfect wood, called *alburnum*, having all the fibrous structure, cells, tubes, and consistence, of timber. In this manner, the diameter of

all dicotyledonous stems are annually enlarged by concentric layers, the pith being in the centre of the whole. These layers of wood are composed of a mass of ligneous fibres, closely and longitudinally arranged, extending from the base to the summit of the trunk, and to that of every branch of the spreading head. The fibres are imbedded in dense cellular matter, the cells of which are placed horizontally between the bundles, and, being distended in the line of their position, give thickness to the alburnous layer.

The number of the layers, reckoning from the pith to the bark, on one side of a transverse section of the butt or trunk, indicates the age of the tree exactly; for the layers never run into each other, nor do they increase or diminish after they are once imposed.

After the tree has passed its mature age, it at last begins to decay; the first imposed layers next the pith fail first; and this decay at the heart extends outwardly, till the trunk becomes a hollow cylinder, when the whole is laid prostrate by the wind. This happens sooner or later, according to the durability of the timber. Some kinds, from the light, porous character of the wood, and aqueous quality of the sap, perish in a few years; others, from the density of the grain, and preservative quality of its concreted juices, resist decay for many years.

The stalk of the seedling rises from the ground with its coat of *bark*, consisting of a layer of green matter, covered by a thin cuticle. This ever remains on the exterior of the greater number of trees, and is distended as the internal growth increases. Some few trees and shrubs discharge their bark every third or fourth year;

but on the greater number the outer bark remains, and is either rent into longitudinal irregular furrows, or stretched horizontally. At the end of the second year, the second layer of bark within the first becomes visible, and takes the name of *liber*, a new layer of liber being formed within the former in every year during the life of the tree. The diameter of the tree is thus increased by a new layer of alburnum, or white wood, and a new layer of liber.

Branches are only subdivisions of the trunk, being quite similar in structure. They differ much in the manner of their divergence, being mostly irregular, and spreading obliquely forward. Others, as the pine tribe, are regularly branched from bottom to the top in annual growths; the stem rising erect, and the branches stretching out horizontally in every direction.

Leaves are the grand ornaments of plants; from their numbers, position, and delicacy of organization, they are destined to effect some important office in the economy of the plant. They are, however, only temporary organs, being articulated with the surface of the bark, and always seated upon or near the buds. Those of deciduous trees or shrubs drop or wither as soon as the summer growth is over. Some of both of those descriptions retain their leaves to the second or third year; hence they are called *evergreen;* and some of the pines and firs retain them for many years.

The web of the leaf is filled up between the veins by cellular tissue, having a thin, porous cuticle both above and below. The structure of the upper and under surfaces of the leaves is not alike; one is supposed to be furnished with excretory, and others with

incretory organs. Water plants, whose leaves are constantly submersed, have no cuticle.

Of the *flower* and *fructification*. The members of the flower are the calyx, corolla, stamen, disk or nectarium, pistillum, and receptacle. The *calyx* is the external investment of the flower, and in which it sits as in a cup. The *corolla* is the delicate and usually high-colored row of leaves or *petals* which stand immediately within the calyx.

The *stamens* are placed within the corolla, and are the male parts of the flower, consisting of three distinct members — the *filament*, the *anther*, and the *pollen*, several forms of which may be seen in the annexed engraving. The filament is the stalk; the anther is

the head, and the pollen is the dust discharged from the anther. The pollen is the matter which contains the fructifying principle. The mixture of this with the *stigma*, where the seeds are formed, is necessary to endow them with the principle of vegetable life. The granules of the pollen are of various forms; under the microscope, they appear to be globular, oval, square, and of various other shapes.

The *disk*, or nectarium, is placed near the base of the stamens, and is of various forms. The *pistillum* occupies the centre of the flower, and is the female or re-

productive part of the plant, consisting of three divisions — the seed-vessel at the bottom; the style at the

top; and the stigma between the two. These are usually placed below the anthers, to receive the pollen.

The Linnæan system of classification, as before stated, is founded upon the number, connection, and situation, of the sexual organs of plants — the stamens and pistils. It was intended to comprehend the whole vegetable kingdom, which was arranged in two grand divisions, — namely, plants having visible flowers, (*phænogamia*,) and plants having no visible flowers, (*cryptogamia*.) The whole are included in twenty-four classes; and these classes are subdivided into orders, genera, and species. The terms used to express the classes are compounded of the Greek numerals and the word *andria*, signifying *man*. These classes are subdivided into orders, which are designated from their number of pistils by Greek numerals also, with the addition of the word *gynia*, which signifies *woman*. The following is a summary of the distinguishing traits of the respective classes: —

1. *Monandria*, with one stamen — Marestail.
2. *Diandria*, with two stamens — Speedwell.
3. *Triandria*, with three stamens — Grasses.

4. *Tetrandria*, with four stamens — Bed-straw.

5. *Pentandria*, with five stamens — Primrose.

6. *Hexandria*, with six stamens — Snowdrop.

7. *Heptandria*, with seven stamens — Water-plantain.

8. *Octandria*, with eight stamens — Heath.

9. *Enneandria*, with nine stamens — Flowering-rush.

10. *Decandria*, with ten stamens — Pink.

11. *Dodecandria*, with eleven to nineteen stamens — Agrimony.

12. *Icosandria*, twenty or more, inserted into the calyx — Rose.

13. *Polyandria*, twenty or more, inserted into the receptacle — Poppy.

14. *Didynamia*, two long and two short — Foxglove.

15. *Tetradynamia*, four long and two short — Wall-flower.

16. *Monadelphia*, filaments combined in one set — Geranium.

17. *Diadelphia*, filaments united into two sets — Pea.

18. *Polyadelphia*, filaments united into more than two sets — St. John's Wort.

19. *Syngenesia*, anthers united into a tube, flowers compound — Thistle.

20. *Gynandria*, stamens situated upon the style, above the germen — Orchis.

21. *Monœcia*, stamens and pistils in different flowers on the same plant — Spurge.

22. *Diœcia*, stamens and pistils in separate flowers and on different plants — Willow.

23. *Polygamia*, stamens and pistils, united or separate, on the same or on different plants, and having two different kinds of perianth — Orache.

24. *Cryptogamia*, stamen and pistils not visible — Moss.

The preceding *classes* are arranged according to the number of stamens. The *orders* are twenty-six in number, arranged according to the number of the pistils of the flowers.

ZOOLOGY.

Having given a sketch of the *mineral* and *vegetable* kingdoms, we now come to Zoology, which is the science of the *animal* kingdom, and embraces the natural history of those beings *which live, move, and feel* — from man, the head of creation, to the coralline and the sponge. It includes alike the elephant and the whale, with the minute animalcules of which a thousand may live in a drop of water, or ten thousand in the stalk of a common plant. Of this great and interesting subject, we can give but a brief outline.*

All natural objects with which we are acquainted by means of our senses, are separated into two great divisions — namely, the *organic* and the *inorganic*. These are distinguished by their laws, which draw a decided line between them, and the boundaries of which are therefore sufficiently defined. The organic division comprehends all bodies endued with vitality, or possessing the principle of life, and therefore includes animals and plants; the inorganic embraces all those objects which are destitute of life, and of course comprehends the mineral kingdom.

The phenomena manifested by all organic bodies are the results of an inherent power, which is generally

* For a further account of animals, see the "World and its Inhabitants," and "Anecdotes of Animals."

termed *vital principle* — a power, the essence of which is enveloped in mystery, and upon which science sheds no light. The general results of this power may be said to consist in a series of internal movements or actions, having no relation to the laws of chemistry or mechanics, and which, enduring for a certain definite period, produces those external characters by which we at once know an organized being; namely, its shape and structure, its growth by the absorption and conversion, into a part of itself, of extraneous matter, and its power of resisting, during an appointed time, the influence of external agents.

Hence organic bodies seem to maintain a constant struggle with the elements around them, perpetually resisting and making good the losses which their actions and influences occasion; perpetually throwing off those particles which are no longer fit for the keeping up of the body's integrity, and taking up others, which they mysteriously convert into a portion of themselves — thus constantly laboring till death.

Inorganic matter does not increase by powers within itself, or resist external agents by the operations of a vital principle. Its laws are those only of mechanics, chemistry, and electricity.

Organic bodies, therefore, include animals and plants. Such is the resemblance between some plants and the lowest grades of animals, that certain naturalists maintain that the two kingdoms run one into the other, and that there is no defined boundary between them. It is said that some plants appear to possess *feeling*, as there are species which shrink from the touch; and that others display *intelligence* — as, for instance, a potato,

growing in a cellar, will wind around a barrel, or other obstructing object, and reach forward toward a window, to obtain light and air. While we admit the truth of these facts, we may still doubt the inference. Because we cannot see the point of division, we must not conclude that it does not exist, particularly when a large survey of the subject seems to suggest a plain design, on the part of the Creator, to separate them. The following are some of the characteristic distinctions between the vegetable and animal kingdoms: —

The power of voluntary motion, which animals in the aggregate possess, demands an adaptation of the organs of nutrition, and hence is derived their first and leading character, namely, an *internal apparatus* for the reception of food, in which it undergoes certain changes before its admission into the system; an admission effected by a multitude of minute tubes or vessels, all originating within this apparatus. Plants are rooted to one spot; they cannot employ voluntary motion in the search, or reception, of food; they have no internal digestive apparatus, and the absorbing tubes of nutriment all arise from the external surface. The aliment taken in by animals has to undergo various operations before it forms a juice proper for absorption; but the atmosphere and the earth present, to vegetables, juices already prepared, and which may be absorbed immediately.

Animal bodies, as they have functions more numerous and varied than plants, possess, with a structure accordingly more complicated, a circulatory system, comprehending the arteries and veins, by which their fluids are diffused — not, as is the case with plants, by

the influence of heat and atmospheric action, but by internal innate energies.

Animals differ from plants in the chemical analysis of their constituent principles. The essential elements of organized matter appear to be *carbon*, *oxygen*, *hydrogen*, *azote* or *nitrogen*, together with *alkaline* and *earthy salts:* now, the solid parts of all plants contain *carbon*, *oxygen*, and *hydrogen*, but *no azote*. The solid parts of animals consist principally of lime or magnesia, united with carbonic or phosphoric acids; and in those beings, of both kingdoms, which appear to be destitute of solid parts, the difference is even still more wide; the *gum* or *mucilage* of soft plants exhibiting no trace of *azote*, which enters as a constituent into the *gelatine* or *albumen* of soft animals.

Atmospheric air and water are the two sources whence the plant derives the principles necessary for the maintenance of vitality. Water is composed of oxygen and hydrogen; air, of oxygen, azote, and carbonic acid, which is a combination of oxygen and carbon.

Now, of these elements, the vegetable retains, as essential to its composition, the carbon, the hydrogen, and part of the oxygen; and exhales or throws out the azote and superfluous volume of oxygen. The essential function, indeed, of vegetable life seems to be the exhalation of oxygen — an operation requiring the presence of that universal stimulus of nature, light.

The principles of vegetable composition, — namely, carbon and hydrogen — enter also, as a source of mediate or immediate nutriment, into the composition of animal bodies. But the constitution of animals de-

mands that a great portion of this hydrogen and carbon should be disposed of from time to time, and that azote should be absorbed. This operation is effected through the medium of the atmosphere, the oxygen of which, combining with the carbon and hydrogen of the blood, is exhaled with them in the form of carbonic acid and water, the azote appearing to remain.

Plants and animals may thus be said to become mutual sources for the production of the elements each requires. The relations they bear to the atmosphere are inverse. The former demands water and carbonic acid, and the latter produce it: animals demand oxygen, and the vegetable creation is perpetually exhaling it.

Having thus separated the animal from the vegetable kingdom, we have only space to exhibit the general divisions under which scientific men have arranged all that has a claim to animal existence, with a few general observations upon the great classes of the animal kingdom.

The woods and fields resound on every side with the cries and voices of creatures varying in form and nature; the air is peopled with busy tribes, that wander through its boundless regions; the wing of the bird rustles as it passes us, and myriads of insects are dancing in the sun; the waters teem with life; the ocean, the mighty ocean, is replete; even the "drop upon the bucket" is a lake to multitudes of animalcules, that rejoice and multiply in its mimic floods, or pine and die as it evaporates. We cannot pluck a leaf from a tree, and examine it, but we discover it to be a little world, peopled with pygmy inhabitants, that play their part in the balance of creation—a part which may,

indeed, escape the researches of the philosopher, but which infinite wisdom has appointed. Diversified, however, and multitudinous as they are, they admit of arrangements or classifications which unravel the intricacy of the subject, and divest the study of its apparent difficulties. It was a want of this system which has rendered the works of the ancients, on natural objects, little more than records of disjointed facts or opinions, without mutual bearing, or order, or plan, and without a definite end. Hence the little comparative progress in the natural sciences, and the mistakes and absurdities which we find to have prevailed among nations the most civilized and refined. Modern science received a new impetus from the writings of Bacon, Ray, and Linnæus, which has regulated inquiry, and produced method and order. Among the philosophers of modern times, Cuvier is preëminent, and his general outline is that which is now most commonly received. He divides the animal kingdom into four grand divisions, namely, —

1. Animalia Vertebrata. — Vertebrate animals, having a brain enclosed in an osseous covering, or skull, and a vertebral column, — as quadrupeds, birds, reptiles, and fishes.

2. Animalia Mollusca. — Molluscous animals, without any internal skeleton, but whose muscles are attached to a soft skin, often enclosed in a hard case, or shell of lime, as oysters, clams, &c.

3. Animalia Articulata. — Articulated animals, in which the body is divided by transverse folds into a certain number of rings; the integuments are sometimes hard, sometimes soft; but the muscles are always

attached to the interior; the trunk is often furnished with many limbs, consisting of numerous joints, but is often also deficient — such as insects; crustaceous animals, as lobsters, &c.

4. ANIMALIA RADIATA. — Radiated animals, or zoophytes, in which the organs of movement are not disposed symmetrically on each side, but consist of an uneven number, disposed like rays round a centre, an instance of which is furnished in the five-fingered Jack; they possess no nervous system, nor particular organs of sense — barely traces of a circulation; and approach in their structure the character of plants.

VERTEBRATA.

Vertebrate animals are distinguished by an internal bony framework, or skeleton, which affords solidity and support. Their body is composed of a head, trunk, and limbs: the head consists of the skull, which encloses and protects the brain; and of the face, which embraces the organs of taste, smell, sight, and hearing: the head rests upon, or is attached to, the vertebral column, which is composed of a number of bones movable one on another, and forming altogether a canal for the *medulla oblongata*, or spinal marrow. The limbs never exceed four, and are in pairs; but sometimes one pair is wanting, sometimes both. The blood is always red.

This great family is divided into four classes: —

1. *Mammalia*, or mammiferous animals, including man, and most quadrupeds.

2. *Aves*, or Birds.

3. *Reptilia*, or Reptiles.

4. *Pisces*, or Fishes.

The *mammiferous animals* are those which suckle their young. They are placed in the first class, as being the most perfectly organized, possessing the most acute senses, and the highest degree of intelligence. This class contains the following orders: —

1. *Bimana*, man, only one species.

2. *Quadrumana*, four-handed animals, as monkeys, apes, and baboons, of which there are more than a hundred species.

3. *Carnivoræ*, or *Carnaria*, butchering animals, including bats, bears, weasels, the wolf, dog, fox, hyena, lion, tiger, and the rest of the cat family.

4. *Amphibia*, the seal kind, including the walrus, &c.

5. *Marsupialia*, or pouched animals, including the opossum, kangaroo, &c.

6. *Rodentia*, or gnawing animals, as squirrels, rats, mice, beavers, rabbits, &c.

7. *Edentata*, without front teeth, as the sloth, armadillo, ant-eater.

8. *Pachydermata*, thick-skinned animals, including the elephant, rhinoceros, hippopotamus, hog, horse, camel, giraffe, lama, deer, goat, sheep, and ox.

9. *Cetacea*, the whale kind.

All the mammalia have a double heart, with two ventricles for propelling the blood; one systematic, or propelling it over the whole body, and the other pulmonic, or sending it to the lungs; and they have also two auricles as appendages to the heart—one for receiving the blood from the lungs, and transmitting it to

the systematic ventricle; and the other for receiving the blood from the system generally, and transmitting it to the pulmonic ventricle.

The blood of all is red and warm, but differs in its temperature in different species. It is aërated wholly in the lungs, and not partially by air-cells or the coats of the arteries, as in birds; and it is more minutely distributed over the system than in any other class of animals. They have also the nervous system — upon which, as we usually suppose, sensation and animal intelligence more immediately depend — much more developed than any other animals; and therefore, though there are great differences among them, they are, taken all together, much more intelligent, docile, and capable of training, than any of the other classes of animals.

They are also the animals which are most useful to man; and, if the expression may be allowed, they are most kindred to him. They bear a part with him in his labor, their flesh supplies him with his best food, and their covering furnishes him with his warmest and most wholesome clothing. They also show attachments to man which are not shown by any other animals; and many of them have their affection unshaken by even very severe ohastisement.

Mammalia are also more easily studied than any of the other classes of animals. They, generally speaking, are, with ourselves, inhabitants of the surface of the earth; for though a few live habitually in the water, a few others under ground, and a few others, still, make their way through the air by means of flying membranes, yet the characteristic locality of the whole

mammalia is the surface of the ground. Generally speaking, too, they do not retreat into holes and hiding-places, as is the case with most ground animals of other orders; they come out openly, and, in the majority of instances, to the day, so that their manners are much more easily studied than those of any other animals.

The mammalia have, accordingly, attracted the attention of mankind in all ages. We find some of the most beautiful allusions to their habits in the writings of the prophets and poets of the Jews, which leave not the least doubt that, whether they had a regular system of the natural history of mammalia or not, they were well acquainted with the nature of the animals.

It is impossible, in the compass of the present volume, to enter into particular descriptions of the various species which belong to this interesting class of the animal kingdom. It may be proper, however, to say something of him, of whom it is written, "And God said, Let us make man in our own image, after our own likeness."—"So God created man in his own image, in the image of God created he him; male and female created he them."

Of man, there is but one species, and one genus. Confining our attention to him in a merely physical point of view, he is the most perfect of all terrestrial beings; not, indeed, in size or animal strength, for in these qualities many excel him, but in the refined, the exalted plan and model upon which he is constructed. The eagle, it is true, may have a more powerful vision; the hare be more alive to every sound; the wild dog or vulture may catch the faintest scent upon

the gale; but in man there is a nice balance, an adjustment, a felicitous accuracy of the senses, which thus expressly tend to his elevation and happiness, and, at the same time that they minister to his pleasure, enable him to obtain an intimate and minute acquaintance with the properties of the world around him. Hence the voice of melody; the colors of earth and sky; the odors of spring; the fruits of summer; the glorious sun, and the spangled canopy of heaven, are sources of gratification and delight to him. Language, in which he can convey his wants, his desires, and the most abstract ideas of his mind, is his alone; and his alone are reason and an immortal soul.

While, however, on the topic of man's physical superiority, we cannot omit noticing a few circumstances, because peculiar to man, at once proclaiming his own dignity and his separation from inferior creatures; we mean his attitude, the freedom and exquisite mechanism of his hands, and his natural deficiency in weapons of aggression or defence.

With the attitude of man we naturally associate ideas of exaltation; and this attitude is, in truth, connected with his moral greatness; no quadruped approaches him in volume or extent of brain; and the blood necessary for an organ so developed is carried to it by arteries, which do not subdivide, as in most quadrupeds, but allow that full and free circulation its energies require; hence a horizontal position would induce a perpetual liability to apoplexy, and render every bodily or mental exertion a hazardous experiment.

Man — sustaining himself on his feet alone — pre-

serves the entire liberty of his hands; and the situation of these organs is that which is best calculated to render them available and useful. But, great as are the advantages derived from their liberty, more are attributable to their structure. The human hand is strong and powerful, but, at the same time, exquisitely susceptible of impressions, and gifted with the most delicate tact. Every finger, except that called the *ring finger*, is capable of independent movements — a power possessed by no other animal; and the thumb is so elongated as to meet readily the tips of any of the fingers: the fingers themselves, and especially the pulpy tips at their extremities, are freely supplied by a nervous tissue, which communicates a discriminating sensibility peculiar to our race. Hence the admirable fitness of the hand for the apprehension and examination of the minutest objects, and the precision with which its actions are executed.

Man possesses neither offensive nor defensive weapons; but this very deficiency adds to his improvement, inasmuch as it throws him back upon his internal resources, and calls forth the energies of his mind. His first step in civilization is to clear out a spot of ground for his dwelling; resist the inroads of the wild and ferocious animals; drive to a distance or exterminate the intractable; and subdue the more docile to himself. Art supplies the means which nature has withheld; and the rude hunter of the forest founds an abode, and rears a family, to be the forefathers of a mighty nation.

Multiplying after the deluge, the human race has spread itself over every portion of the globe, and

ramified into a thousand tongues and nations. Capable of inhabiting every climate, and in every situation surrounding himself with the necessaries of life, man peoples the burning regions of the torrid zone, and the ice-girt shores of the Arctic Ocean. To him the mountain, the valley, the morass, and the desert, are alike; and, modifying his food according to locality, he thrives upon rice, and the plantain, and the palm-nut, on the plains of India; upon the raw flesh and blubber of the seal, on the frozen snows of Greenland. Between these points there are innumerable grades and distinctions in habits, in manners, in food, in civilization, and moral qualities; but, different as the tribes into which the human race is divided may appear, they may be ultimately reduced to about five standing varieties, the descendants of a common parent. These have been characterized as the *Caucasian*, which includes the nations of Europe, and such in ancient times as have been most distinguished for civilization and power; the *Mongolian*, to which are referred the mighty empires of China and Japan; the *Ethiopian*, occupying the interior of Africa; the *American;* and the *Malay*, which includes the natives of the peninsula of Malacca, of Borneo, Java, the isles of the Indian Ocean, Australia, and the islands of the Pacific.

It were useless to inquire, and impossible to give any satisfactory solution, or theory, upon which to account for the hereditary characteristics which attach to these different varieties of mankind: climate, food, modes of life in remote ages, a primeval peculiarity in the early progenitors, which has continued itself to their latest descendants, or causes now unknown, may have

all, in their turn, contributed to the diversity that exists. One feature, however, which pervades human nature through all its varieties, in every age, in every nation, proclaims a common origin. History, however remotely we trace its records, whether sacred or profane, discovers this trait in every page, and our own experience has made us acquainted with it: we mean the universal degeneracy of the human race — a fact which, however men may have differed as to its cause, has in every generation been acknowledged; and, as if the memory of Eden still lingered on the earth, has been blended with a looking-back to a traditionary period of innocence and purity before "all flesh had corrupted his way;" and the sage and the poet have alike lamented the long-passed golden age.

The class *Aves* furnishes, in the admirable adaptation of structure to the modes of life in the several species, a most interesting theme of inquiry; that of the *Reptilia* abounds in various and wonderful phenomena; and the *Pisces*, inhabitants of the world of waters, may well excite our admiration by their variety and their peculiar endowments.

Nor are the *invertebrate* animals without their claims to our attention; but our limited space compels us, reluctantly, to deny them a particular description.